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PEACH HARVESTING AND STORAGE INVESTIGATIONS[1]

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Peach production in the Okanagan Valley of British Columbia is undergoing a period of rapid expansion. In 1942 the peach crop amounted to almost 1,000,000 crates, more than 4 times the production in 1933. A recent survey shows approximately 66,000 peach trees under 5 years of age and 82,000 trees from 6 to 10 years old. With due consideration for the removal of older peach trees and undesirable varieties, the increase in peach tree population has amounted to over 30% in the past 5 years. New peach orchards have been planted in more favourable locations, and tested varieties are being used which will reduce the hazards of production and result in heavier crops of peaches in the near future.

In order to deliver this increasing tonnage to fresh fruit markets and processing factories in attractive condition greater attention must be paid to harvesting and storage procedures. Peaches which are picked immature fail to develop good quality, whereas those which are left too long on the trees become soft and unfit to withstand commercial handling. Cold storage serves to hold fruit in good condition awaiting market requirements, retards ripening, and lengthens storage life, but only up to a certain point. Peaches held in cold storage too long lose their capacity to ripen, and suffer low temperature breakdown.

Low temperature breakdown as it occurs in Okanagan grown peaches varies somewhat with the variety and the season. With the earlier varieties such as Rochester and Vedette, the fruit tends to become dry, fibrous, and mealy, losing its juicy texture. A transverse section of the flesh shows a browned flushed area around the periphery which gradually extends inwards. When held at room temperature after removal from cold storage the fruit remains in a rather firm condition and does not soften normally, but finally breaks down and becomes mushy. With the J. H. Hale and Elberta varieties, the peaches upon removal from storage are firm and attractive in appearance, but after a few days at 65° F. become soft and spongy, discoloured in the flesh, stringy and coarse in texture, and quite inedible. They are particularly deceiving as their outward appearance upon removal from storage gives no indication of their true internal condition.

It was primarily to secure information regarding means of delaying and, if possible, preventing the onset of low temperature breakdown in Okanagan grown peaches that the experiments reported in this paper were undertaken.

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REVIEW OF LITERATURE

Breakdown in cold stored peaches has been reported upon by several investigators. Harding and Haller (9) found that the first indication of breakdown was a water-soaked appearance around the stone. In later stages, the water-soaked areas became larger and turned brown, and eventually all the flesh became brown and mealy. In South Africa, Davies *et al.* (4) mention two types of peach breakdown. With Type A the flesh becomes mealy and discoloured with a poor or objectionable flavour, in which case the fruit is described as "wooly". Type B, which is not as common, is characterized by a translucency of the flesh around the stone, which may extend to the skin and cause tissue discolouration, although affected fruit is usually juicy and of good flavour.

Breakdown in peaches results from over-storage at temperatures lower than 50° to 55° F. A storage temperature of 32° for peaches has been found by Harding and Haller (10, 11), Haller and Harding (9), Fisher and Britton (8), Smith and Willison (14), Adam (1), Davies *et al.* (4, 5) to retard development of breakdown as compared with storage at 36° and 40° F. Although the recommended storage temperature for peaches is 32° F., breakdown occurs in fruit held at this temperature after periods of 1 to 5 weeks depending on variety and season (11, 15, 8). It is probable that growing temperatures at the time the fruit matures play an important role in determining susceptibility to low temperature breakdown, for Fisher and Britton (8) and Willison (15) report quicker development of breakdown in varieties such as Hale and Elberta which mature late than in varieties such as Rochester and Vedette which mature early. Furthermore, British Columbia grown Elberta and Hale develop breakdown after 1 to 2 weeks at 32° F., whereas the same varieties grown under the more southern climate of Virginia are reported by Harding and Haller (11) to remain in good condition in 32° F. storage for 3 to 4 weeks.

Davies *et al.* (4, 5, 6) report that with white fleshed peaches grown in South Africa, breakdown (woolliness) may be controlled successfully by pre-ripening the fruit before placing it in cold storage. The higher the pre-ripening temperature the shorter is the period of delay necessary to control breakdown. Thus at 75° F. a period of 2 to 3 days is required to reduce breakdown to reasonable proportions whereas it takes 4 or more days at 65° F. and 8 or more days at 50° F. (5, 6). Davies *et al.* (6) did not obtain as good response from delayed storage in controlling breakdown with Elberta as they did with other varieties. Three days of pre-ripening at 65° F. followed by storage at 34° prolonged keeping life at least 1 week as compared with fruit stored immediately at 34° F. Fisher and Britton (8) report that development of breakdown in yellow fleshed peaches is delayed by deferred storage treatment.

In a recent study of "woolliness" in Peregrine peaches (white flesh), Reyneke (13) from South Africa states that from time of picking to the final stage of eating ripeness, the fruit passes from a firm juicy condition to a temporary juiceless condition and finally to a juicy eating condition. Fruit placed in cold storage when in the half-ripened juiceless condition develops "woolliness", whereas fruit placed in cold storage in the initial or final "juicy" stages ripens normally, free of "woolliness".

FIGURE 1. Peach orchard in the Okanagan Valley of British Columbia.

FIGURE 2. Type of tree from which peaches used in these experiments were harvested.

It is reported from Australia (3) that at 34° F. storage life of peaches was increased from 3 weeks to 4 and 6 weeks respectively by storage in atmospheres containing 5 and 10% carbon dioxide, that controlled atmosphere fruit ripened almost as well as that stored in air, but that overstored peaches developed a fermented flavour on ripening. Huelin *et al.* (12) from Victoria, Australia, report that while the average cold storage life of peaches at 32° F. is about 6 weeks, storing in controlled atmospheres containing 8 to 10% carbon-doixide lengthened the storage period by about 10%. Allen and Smock (2) also report that exposure of J. H. Hale peaches for 6 days to 15% carbon dioxide at 45° F. retarded ripening as compared with air-stored checks, and that quality was excellent. Gerhardt *et al.* (7) found that with J. H. Hale and Elberta peaches held in 10 or 20% carbon dioxide at 36° F. or 45° F., colour development and softening were retarded in storage, and the fruit took slightly longer to ripen than checks stored in air, but total keeping life of treated fruit was similar to that of untreated fruit. Fisher and Britton (8) obtained discouraging results from storage of Rochester, Vedette and Valiant peaches in an atmosphere of 7.5% of carbon dioxide at 40° F.

EXPERIMENTAL

Experiments were conducted at the Summerland Experimental Station in 1940 and 1941 to secure information concerning the influence of maturity at picking and length of delayed storage period on the behaviour of cold stored peaches.

Seven varieties of peaches, Rochester, Golden Jubilee, Vedette, Valiant, Veteran, Elberta, and J. H. Hale were picked both mature and immature and stored with and without pre-ripening treatment at 40° and 32° F. Records were taken of firmness, skin and flesh colour, and soluble solids content at picking time. Removals of peaches from cold storage to a 65° F. ripening room were made at weekly intervals to determine texture and quality of the fruit and evidence of low temperature breakdown. In addition to firmness and quality observations, determinations were made of respiration intensity and soluble pectin formation during ripening.

A further experiment was conducted to secure information concerning the influence of carbon dioxide on the storage life of Rochester and J. H. Hale.

Characteristics of Mature and Immature Peaches

In order to provide an accurate description of the condition of the fruit at the two stages of harvesting maturity used in these studies, records were made of flesh and skin colour, firmness and soluble solids content. The colours were taken on the unblushed side of the fruit using Ridgway's Colour Standards, soluble solids determined with a Zeiss refractometer, and firmness ascertained by means of a Ballauf pressure tester using both the 5/16-inch and 7/16-inch plungers on the unpared flesh of the fruit.

Some of the results secured are presented in Tables 1 and 2.

TABLE 1.—SKIN COLOUR, FLESH COLOUR AND FIRMNESS OF MATURE PEACHES, 1940

Variety	Date of harvest	Skin colour	Flesh colour	Firmness in pounds	
				$\frac{5}{16}''$ point	$\frac{7}{16}''$ point
				lb.	lb.
Rochester	July 29	Straw yellow	Mustard yellow	15.7	22.6
Golden Jubilee	Aug. 2	Straw yellow	Straw yellow	14.3	23.3
Vedette	Aug. 9	Amber yellow	Amber yellow	16.2	21.8
Valiant	Aug. 10	Straw yellow	Amber yellow	14.7	25.3
Veteran	Aug. 9	Mustard yellow	Amber yellow	15.8	19.8
J. H. Hale	Aug. 16	Naples yellow	Maize yellow	16.3	25.1
Elberta	Aug. 29	Naples yellow	Maize yellow	18.8	25.3

TABLE 2.—SKIN COLOUR, FLESH COLOUR, FIRMNESS AND SOLUBLE SOLIDS CONTENT OF PEACHES, 1941

Variety	Mature				Immature			
	Skin colour	Flesh colour	Firmness $\frac{5}{16}''$ point	Soluble solids	Skin colour	Flesh colour	Firmness $\frac{5}{16}''$ point	Soluble solids
			lb.	%			lb.	%
Rochester	Chamois	Amber yellow	14.9	12.1	Deep colonial buff	Barium yellow	19.7	11.5
Vedette	Barium yellow	Citron yellow	15.7	11.1	Light dull green-	Citron green yellow	19.1	10.5
J. H. Hale	Colonial buff	Naples yellow	15.8	11.1	Primrose yellow	Barium yellow	18.8	10.9
Elberta	Reed yellow	Barium yellow	16.7	11.4	Deep sea-foam green	Reed yellow	21.2	10.8

From the data presented in Tables 1 and 2 it is apparent that there were slight differences in the colours of "mature" peaches in 1940 and 1941. Nevertheless in both years the fruit of all varieties when classified as "mature" showed no green shades but rather the warmer shades of yellow in both skin and flesh. Picked at this stage the fruit was in good firm handling condition as shown by the pressure tests. It will be noted that the firmness of mature samples averaged from 14 to 18 lb. with the $\frac{5}{16}$-inch plunger and from 20 to 25 lb. with the $\frac{7}{16}$-inch plunger.

With regard to the fruit classed as "immature", Rochester and J. H. Hale had yellowish skin and flesh colour, whereas Vedette and Elberta were still tinged with green. Using the $\frac{5}{16}$-inch plunger the immature fruits averaged about 20 lb. in hardness. Differences in percentage of soluble solids between mature and immature peaches were small.

Influence of Maturity and Storage Treatments on Keeping Life of Peaches

Immediately after picking, the fruit was taken to a packing house and packed in dry wraps in standard peach boxes. At least one box of each variety was placed at once under each of the following conditions: 65° F. ripening room, 40° F. storage and 32° F. storage. In each of these rooms the atmospheric humidity was maintained close to 85%. Additional boxes of comparable fruit were delayed for from 1 to 5 days on the packing house floor before being placed under refrigeration. In the packing house, temperatures ranged from 60 to 80° F. when mid-season varieties such as Rochester and Vedette were being picked, and from 60 to 65° F. at the time J. H. Hale and Elberta were picked. Relative humidity was about 50% in the packing house throughout the harvesting season.

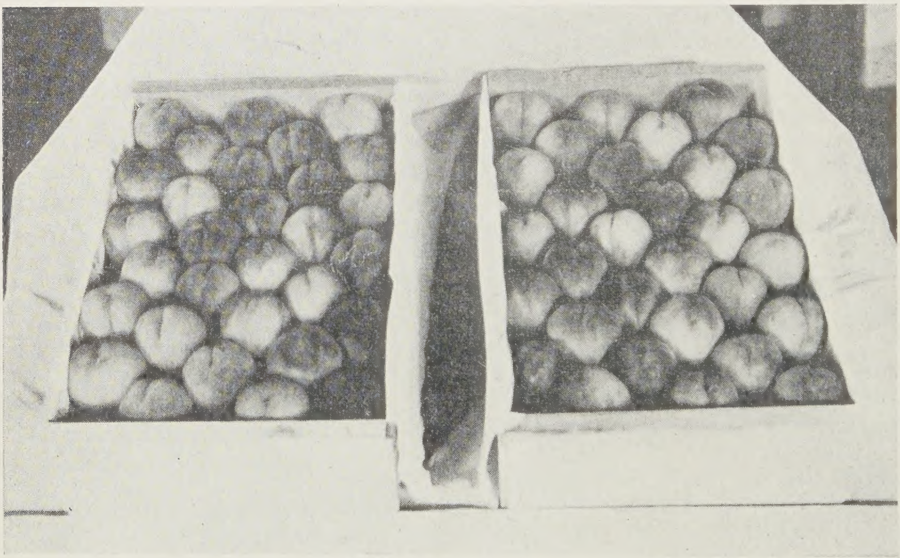

FIGURE 3. Twenty-pound double layer crate in which peaches used in these experiments were packed.

As previous work (8) had indicated that the effectiveness of delayed storage was dependent on the degree of ripeness attained by the peaches before they were placed under refrigeration, at least 1 box of each variety and each maturity was held in the packing house until the fruit had softened to a pressure of 12 to 10 lb. as measured by the 5/16-inch point on the Ballauf pressure tester. It was thought that at this firmness the fruit would have reached a stage of pre-ripening sufficient to retard the onset of low temperature breakdown but would still be firm enough to withstand commercial handling. The length of delay necessary to secure the required degree of softening was influeuced by the maturity of the fruit when picked and also by variety. Data substantiating this statement are presented in Table 3.

TABLE 3.—SOFTENING OF PEACHES DURING DELAY IN PACKING HOUSE AND IN STORAGE AT 32° F.

Maturity and variety	Firmness by pressure test using $\frac{5}{16}$-inch point									
	Peaches stored at once					Peaches stored after delay*				
	At picking	Weeks at 32° F.				At picking	Weeks at 32° F.			
		2	3	4	5		2	3	4	5
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Mature										
Rochester	14.9	9.4	9.4	9.0	8.2	9.6	6.5	6.2	4.7	4.5
Vedette	15.7	15.2	9.8	9.8	10.0	12.0	7.3	6.9	6.4	6.6
J. H. Hale	15.8	15.4	14.3	Breakdown		9.1	8.7	9.5	Breakdown	
Elberta	16.7	15.0	14.6	Breakdown		9.9	9.7	10.4	Breakdown	
Immature										
Rochester	19.7	16.7	16.7	15.4		11.0	7.7	7.0	6.2	5.2
Vedette	19.1	16.3	16.3	15.1		12.6	8.6	6.9	8.0	4.5
J. H. Hale	18.8	18.5	18.5	Breakdown		12 1	8.3	7.6	Breakdown	
Elberta	21.2	21.2	19.7	Breakdown		11.8	10.9	11.4	Breakdown	

* Delay in packing house 1 day for mature and 2 days for immature Rochester and Vedette, 3 days for mature and 5 days for immature J. H. Hale and Elberta.

The data presented in Table 3 indicate that the Rochester and Vedette varieties softened very rapidly when held at packing house temperatures prevailing at time of harvest. In fact fruits of these varieties picked in the mature condition with a hardness of 16 to 15 lb. softened about 4 lb. in 1 day with the result that 24 hours after harvest they tested 12 to 10 lb., indicating that the desired amount of pre-ripening had taken place. Similarly immature fruit of these varieties picked with a hardness of 20 to 19 lb. softened to a test of 13 to 11 lb. in 2 days. With J. H. Hale and Elberta, softening proceeded more slowly, mature fruit reaching the desired condition of pre-ripening in about 2 days and immature fruit in 5 or 6 days.

From Table 3 it is also evident that the peaches continued to soften during storage at 32° F. In fact Rochester and Vedette softened quite materially with the result that fruit picked in the mature condition and delayed 1 day before storage was practically eating ripe after 4 weeks in cold storage. In contrast, J. H. Hale and Elberta softened slowly for the first 2 weeks in cold storage and then developed low temperature breakdown.

Samples of fruit receiving the various storage treatments were removed from the 40 and 32° F. rooms to a 65° F. ripening room at weekly intervals. Observations were then made daily to determine time required to reach eating ripeness, time to become over ripe, development of quality and prevalence of low temperature breakdown. Some of the data secured are presented in Table 4.

It will be noted from the data incorporated in Table 4 that with all varieties studied the length of time that the fruit could be held at 32° F. or 40° F. without initiating low temperature breakdown was comparatively short. In peaches held at 32° or 40° F. for more than 5 weeks, breakdown invariably developed regardless of whether the fruit was held for 1 or more days in the packing house prior to cold storage.

Table 4.—Effect of storage treatment on breakdown of peaches

Maturity and variety	Number of weeks storage before onset of breakdown					
	1940			1941		
	Imme- diate 32° storage	Delayed* 32° storage	Imme- diate 40° storage	Delayed* 40° storage	Imme- diate 32° storage	Delayed* 32° storage
	weeks	weeks	weeks	weeks	weeks	weeks
Mature						
Jubilee	2	3	1	3		
Rochester	3	5	2	3	4	5
Vedette	2	3	2	4	3	4
Valiant	3	4	2	4		
Veteran	2	2	2	2		
J. H. Hale	2	2	2	4	1	2
Elberta	1	2	1	2	1	2
Immature						
Jubilee	2	3	2	3		
Rochester	3	3	3	2	4	5
Vedette						
Valiant	2	4	2	4		
Veteran	2	2	1	1		
J. H. Hale	2	3	2	4	2	2
Elberta	1	2	1	2	1	3

* Delay in packing house 1 day for mature and 2 days for immature Jubilee, Rochester, Vedette, Valiant, and Veteran, 3 days for mature and 5 days for immature J. H. Hale and Elberta.

With fruit which was cold stored immediately, the period at low temperature necessary to initiate breakdown was materially shorter than when the fruit was subjected to a short pre-ripening period before placing in cold storage. Thus a delay of 1 or 2 days in the packing house made it possible to keep both mature and immature fruit of the mid-season varieties Golden Jubilee, Rochester, Vedette and Valiant from 1 to 2 weeks longer in cold storage than was possible when the fruit was placed in cold storage within a few hours after being picked. With the Veteran variety delayed storage failed to lengthen storage life, and with J. H. Hale and Elberta delays of 2 to 3 days for mature and 5 to 6 days for immature fruit were not always effective in retarding the onset of breakdown. Furthermore, even when ideal pre-ripening treatments were given, these varieties often remained in marketable condition as long when held at prevailing packing house temperatures as when subjected to cold storage treatment. Data supporting this statement are presented in Table 5.

From the figures in Table 5 it is evident that the marketable life of mid-season varieties such as Rochester and Vedette was materially lengthened by cold storage, especially when appropriate pre-ripening treatment was given. On the other hand with J. H. Hale and Elberta, cold storage even when preceded by a delay at packing house temperature, was not very effective in prolonging storage life. In fact these varieties, which keep well for several weeks at packing house temperatures, have proved so subject to low temperature breakdown when grown under British Columbia conditions, that it appears advisable to keep them away from cold storage.

TABLE 5.—EFFECT OF STORAGE TREATMENT ON LIFE OF PEACHES

Maturity and variety	Total days in marketable condition, including periods in packing house, under refrigeration and in 65° ripening room						
	1940					1941	
	65° F. room	Immediate 32° storage	Delayed 32° storage*	Immediate 40° storage	Delayed 40° storage*	Immediate 32° storage	Delayed 32° storage*
	days	days	days	days	days	days	days
Mature							
Jubilee	8	18	24	11	24		
Rochester	11	27	39	19	24	34	38
Vedette	12	24	25	19	31	39	34
Valiant	13	29	34	20	34		
Veteran	13	22	22	19	17		
J. H. Hale	33	21	22	23	39		27
Elberta	26	15	15	14	22		14
Immature							
Jubilee	14	20	27	20	26		
Rochester	18	30	30	27	20	34	41
Vedette	21					35	45
Valiant	18	22	33	22	34		
Veteran	14	24	25	13	17		
J. H. Hale	35	21	31	24	39		31
Elberta	33	17	23	14	22		32

* Delay in packing house 1 day for mature and 2 days for immature Jubilee, Rochester, Vedette, Valiant and Veteran, 3 days for mature and 5 days for immature J. H. Hale and Elberta.

The data presented in Tables 4 and 5 indicate that with respect to breakdown and length of marketable period the fruit stored at 40° F. behaved much like that stored at 32° F., with the advantage, if any, in favour of 32° F. storage.

From Tables 4 and 5 it is also evident that fruit picked in the condition described in this paper as "immature" tended to have a slightly longer storage life than that described as "mature" but the differences were small. Furthermore, the quality of the fruit picked "mature" was greatly superior to that picked "immature".

It was also observed that with mid-season varieties such as Rochester and Vedette a short pre-ripening treatment prior to cold storage resulted in reduced astringency, improved texture, and enhanced quality.

Influence of Maturity and Storage Treatments on Soluble Pectin Formation

Information concerning the changes in pectic materials which take place in Rochester, Vedette, J. H. Hale, and Elberta peaches during the ripening period was secured by determining the content of soluble pectin in juice from freshly picked peaches and from similar samples kept for various periods of time in the packing house and in cold storage. In making the determinations the Carre and Haynes (2a) method was used. Some of the data secured are presented in Table 6.

TABLE 6.—SOLUBLE PECTIN FORMATION IN PEACHES DURING DELAY IN PACKING HOUSE AND IN STORAGE AT 32° F.

Maturity and variety	Soluble pectin in 16 cc. of clarified juice												
	When picked	After holding in packing house for				After holding in 32° F. storage for				After holding in packing house and 32° F. storage for			
		1 day	2 days	3 days	5 days	14 days	21 days	28 days	42 days	14 days	21 days	28 days	42 days
	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
Mature													
Rochester	7	33				73			74	134			197
Vedette	24	43	80			36		74		114		148	
J. H. Hale	32		87			38	45			109	113		
Elberta	15		95			92	124			116	121		
Immature													
Rochester	1		80			13			39	121			208
Vedette	3		37	83		10		34		135		158	
J. H. Hale	9				127	36	40			119			
Elberta	5				170	21	53			168	165		

NOTE.—Temperatures in the packing house ranged between 70 and 80° F. when Rochester and Vedette were picked and between 60 and 65° F. when J. H. Hale and Elberta were picked.

It will be noted that with all 4 varieties at time of picking the mature fruit contained much more soluble pectin than the immature fruit. Soluble pectin values increased very rapidly in both mature and immature samples held at packing house temperatures. At 32° F., hydrolysis of insoluble protopectin to the soluble form proceeded at a much slower rate with the result that less soluble pectin had been formed after 2 weeks at 32° F. than after 2 days at packing house temperatures.

With peaches which were subjected to a pre-ripening treatment of 1, 2 or 3 days at packing house temperatures, formation of soluble pectin continued after the fruit was placed in 32° F. storage. On the other hand, with the immature samples of J. H. Hale and Elberta which were held at packing house temperatures for 5 days, formation of soluble pectin had apparently reached its peak and there was a slight decrease after transfer to 32° F. storage. This was probably due to conversion of some soluble pectin to pectic acid.

Comparison of data presented in Tables 3 and 6 indicates that there was a close correlation between formation of soluble pectin and softening of flesh.

Influence of Maturity and Storage Treatment on Respiration

Respiration intensity is considered one of the most reliable indicators of physiological changes occurring in fruit tissue. To provide information concerning the physiological changes occurring in the peaches used in these experiments, respiration determinations were made on mature and immature samples held at packing house temperatures and after being placed in cold storage. For these experiments about 2·5 kilograms of peaches were enclosed in a 4-gallon can with a wide friction-type lid. Two copper tubes were soldered into opposite corners of the tin, one for air intake, the other as the outlet. A constant stream of air was pulled through the tins

over the fruit at a rate of 7 litres per hour, by attaching the respiration unit, with a flow meter, to a constant pressure vacuum line. At intervals, a Truog absorption tower containing glass beads and 50 cc. of 0·114 normal $Ba(OH)_2$ was introduced onto the outlet air line, and the carbon dioxide respired per kilogram of fruit per hour was determined. Some of the results are presented in Table 7.

TABLE 7.—RESPIRATION OF PEACHES DURING DELAY IN PACKING HOUSE AND IN STORAGE AT 32° F.

Maturity and variety	When picked	Respiration rate, cc. carbon dioxide per kg. hr.								
		After holding in packing house for			After holding in 32° storage for			After holding in packing house and 32° F. storage for		
		1 day	2 days	3 days	4 days	15 days	25 days	4 days	15 days	25 days
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc
Mature										
Rochester	14.1	29.3	34.5		4.6	4.0	3.8	4.4	4.4	4.3
Vedette	22.8	40.7	32.7		3.7	3.7	3.5	5.1	5.1	4.8
J. H. Hale	10.8	47.3	16.9		3.2	3.4	3.4	3.6	3.4	3.5
Immature										
Rochester	14.5	30.7	34.5		4.5	4.0	3.8	4.4	4.4	4.3
Vedette	19.4	35.3	30.0	35.0	3.7	3.7	3.5	5.5	5.3	5.5

The data presented in Table 7 indicate clearly that the respiration rate of peaches held at packing house temperatures rose rapidly for a day or two after picking. This rapid rise in respiration rate was probably the climacteric in metabolic activity, but may have been stimulated by the wound injury caused by picking the fruit.

With fruit which was stored at 32° F. immediately after picking, respiration rate was not determined until 4 days after the peaches were placed under refrigeration. By that time respiration had fallen to a low rate which was maintained throughout the storage period. The delayed cold storage lots, once they were chilled to 32° F., respired at practically the same rate as similar fruit which was stored immediately. Only in the case of Vedette was there evidence of a slightly higher respiration rate maintained after delayed cold storage fruit was placed at 32° F. The respiration rate of roughly 4 cc. CO_2 per kg. hr. at 32° F. was in sharp contrast to respiration rates ranging up to 47 cc. for peaches held at 70 to 80° F. The respiration trend of immature fruit closely paralleled that of the mature, except that with Vedette not quite so great a respiration intensity was attained.

Influence of Controlled Atmosphere Storage on the Life of Peaches

To secure information concerning the influence of controlled atmosphere (gas) storage on peaches an experiment was conducted in 1941 with fruit of the Rochester and J. H. Hale varieties.

The fruit was enclosed directly in sealed 4-gallon friction-top cans equipped with a gas sampling outlet and punched with a few small holes for the purpose of restricting ventilation of the atmosphere within the can

so as to allow only sufficient exchange of air between inside and outside to prevent the carbon dioxide content within the can exceeding desired limits. Three CO_2 concentrations, 5, 7, and 9% were used with Rochester and two CO_2 concentrations, 7 and 9%, with J. H. Hale. The peaches were held under these concentrations at 32° F. from time of picking until removal from cold storage. Carbon dioxide concentrations maintained in the fruit containers were subject to fluctuations of 1%, and were adjusted every day or two days following analysis of a gas sample by means of an Orsat analyser. The 2 lots of Rochester were removed from cold storage to a 65° F. ripening room after 25 and 41 days respectively, and the J. H. Hale after 27 days.

With the Rochester variety, after 25 days cold storage in all 3 atmospheres, firmness, length of life, and flavour were not significantly improved over fruit stored in ordinary air for the same period, and at the same temperature. In one respect the fruit was seriously harmed by the carbon dioxide atmospheres, for a large proportion of the peaches showed black injured areas on the skin, $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in diameter. This disorder was progressively worse the greater the percentage of carbon dioxide.

At the second removal of Rochester from 32° F. after 41 days' storage, all lots including the checks were mealy and showed incipient breakdown. There was no increase in the black spotting of the skin but rots had developed in many of the affected areas. These results suggest that with the Rochester variety as grown under Okanagan conditions carbon dioxide storage has no value either as a means of delaying development of mealiness or for prolonging life of the peaches after removal from cold storage.

With the J. H. Hale variety, results were equally disappointing. Controlled atmospheres failed to prevent development of a mealy type of breakdown during a 27-day storage period although the breakdown was worse in the check than in the two treated samples.

DISCUSSION

These experiments indicate that the handling of peaches is a matter which requires very close attention to detail if satisfactory results are to be secured. In the first place full maturity of fruit is essential to the development of a well-flavoured product. Less mature fruit keeps somewhat longer and will soften and become ripe, but is bitter and astringent to taste. Peaches mature so rapidly and in such a short period of time in most years that cold storage often becomes necessary to tide over temporary oversupplies of this commodity and to insure orderly marketing. It is during the period of cold storage at the shipping point, refrigerated transport to market, and storage at the market centres that injury to the keeping life of peaches is most likely to occur.

Peaches handled under the best of conditions show a tendency to develop low temperature breakdown after even comparatively short periods of cold storage. Under conditions of these experiments, the safe cold storage period at 32° F. for mid-season varieties was only 3 weeks, and for the later varieties, J. H. Hale and Elberta, only about 1 week. When held in cold storage for longer periods, there was danger of breakdown in the flesh after the fruit was removed to ripening temperatures.

These findings are substantially in accord with those of Harding and Haller (11) and Willison (15). However, Harding and Haller (11) working in the more southern climate of Virginia found that Hale and Elberta could safely be cold stored at 32° F. for 3 to 4 weeks. The warmer temperatures prevailing in Virginia during the harvesting period probably account in large measure for this difference.

The favourable response of peaches to delayed as contrasted with immediate cold storage seems to be due to the fact that the fruit starts its ripening processes and becomes partially ripened before it is placed at 32° F. Partially ripened fruit is capable of completing its ripening when removed from cold storage after a longer period of refrigeration than fruit cold stored immediately without a period of delay at warm temperatures. Apparently, prolonged periods of refrigeration inactivate the enzyme system of peaches so that they lose their capacity to ripen normally, with the result that the fruit remains hard and then develops internal breakdown. With late maturing varieties such as J. H. Hale and Elberta the cold storage period necessary to inactivate the enzyme system is apparently much shorter than with varieties maturing in mid-season such as Rochester and Vedette. For this reason cold storage of J. H. Hales and Elbertas is not recommended, but rather a common storage temperature of about 55° F.

From a practical standpoint most peaches are held at high temperatures for about a day during the period elapsing between picking and packing, and some pre-ripening of the fruit thus takes place. However, to minimize bruising, peaches which are to receive delayed storage treatment should be packed as soon as received from the orchard, and then allowed to stand in the packing house long enough to achieve the desired degree of pre-ripening.

The results from delayed storage experiments reported in this paper are substantially in agreement with those obtained by Davies *et al.* (4, 5, 6) in South Africa. However, these investigators obtained a more complete control of breakdown than was secured in the present experiments. This may have been due to the varieties of white flesh peaches grown in South Africa which differ from the yellow flesh kinds used for these experiments, and also to the length of pre-ripening given the fruit before storage. Davies *et al.* pre-ripened their fruit to a firmness, in some instances, of 4 lb. as measured with the $\frac{7}{16}$ pressure tester point, which is practically eating ripe, and too soft for commercial handling under British Columbia conditions.

The softening of peaches during storage at 32° indicated that even at low temperatures varieties such as Rochester and Vedette undergo considerable ripening, and are thus less able to stand handling the longer they are held in cold storage. In this connection soluble pectin and respiration determinations which measure the physiological basis for softening of fruit, indicated a steady process of ripening even in 32° F. storage.

While satisfactory results have been reported by several investigators (2, 3, 12) with the use of carbon dioxide atmospheres for lengthening storage life of peaches, experiments with Okanagan grown Rochester and J. H. Hale did not indicate any advantage from this procedure. In fact with the Rochester variety storage in atmospheres containing carbon dioxide induced development of skin injury.

SUMMARY

Harvesting and storage experiments designed to provide information regarding the influence of maturity and delayed cold storage on development of low temperature breakdown in peaches are described and the results presented. Seven varieties were used and the work extended over a 2-year period. Pressure tests were taken of the fruit at picking, and during and after the delayed storage period. Skin and flesh colour and soluble solids content of the juice were determined at harvest. At weekly intervals up to 6 weeks after picking, samples of peaches were removed from cold storage to a 65° F. ripening room for observation. Notes were made on condition, eating qualities, and length of life. Chemical determinations of respiration intensity, and formation of soluble pectin during ripening were carried out. A further experiment dealt with influence of carbon dioxide on the storage life of Rochester and J. H. Hale. The more important findings may be briefly stated.

1. Shades of skin colour and flesh colour of mature and immature peaches were determined according to Ridgway's Colour Chart. These colours varied slightly in the two seasons for given varieties. Such colours as amber yellow, barium yellow, Naples yellow, straw yellow and reed yellow, were characteristic of mature peaches. There was a close similarity between skin colour and flesh colour in any given variety.

2. Mature peaches in ideal shipping condition showed a firmness of 14 to 18 lb. with a $\frac{5}{16}$-inch pressure tester point and 20 to 25 lb. with a $\frac{7}{16}$-inch point.

3. Differences in soluble solids content of mature and immature peaches were too small to make this test of value as a maturity index.

4. When picked in the mature condition suitable for fresh shipment and held at 65° F. peaches remained in good condition for the following number of days: Golden Jubilee 8, Rochester 11, Vedette 12, Valiant 13, Veteran 13, J. H. Hale 33, Elberta 26.

5. Picking in a slightly less mature condition lengthened the life of each variety by a few days but only at the expense of quality.

6. When stored at 32° F. immediately after picking, all varieties except Elberta remained free of breakdown for 2 to 3 weeks in 1940, while Elberta held good for only 1 week. In 1941, J. H. Hale and Elberta remained in good condition for only 1 week when stored immediately at 32° F., while Vedette and Rochester stored satisfactorily for 3 and 4 weeks respectively.

7. Softening of the fruit after picking to a firmness of about 10 lb. as measured with the $\frac{7}{16}$-inch pressure tester point appeared to be the optimum amount of pre-ripening necessary to produce a substantial increase in breakdown-free storage life of peaches without rendering the fruit too soft for commercial handling.

8. With the Golden Jubilee, Rochester, Vedette and Valiant varieties a pre-ripening period of 1 day for mature and 2 days for immature samples prior to cold storage resulted in an increase of from 1 to 2 weeks in the breakdown-free life of the fruit.

9. With Hale and Elberta, which required a longer pre-ripening period prior to cold storage, a delay of from 2 to 5 days was necessary to prolong the breakdown-free life for a week.

10. J. H. Hale and Elberta held at prevailing packing house temperatures of about 65° F. kept in good condition as long as similar fruit receiving delayed cold storage treatment, and longer than fruit placed immediately in cold storage.

11. Pre-ripening did not appreciably reduce the life of peaches after removal from cold storage as compared with fruit cold-stored immediately after picking.

12. Delayed cold storage pre-ripening treatment reduced astringency, and improved texture and quality of peaches.

13. In 32° F. storage, Rochester and Vedette peaches softened gradually. Most lots of pre-ripened Rochester and Vedette, at the end of their safe cold storage period, had softened to one-half their degree of firmness when placed in cold storage. Hale and Elberta softened less rapidly.

14. In the processes of ripening at packing house temperatures, there was a very rapid rate of hydrolysis of protopectin to soluble pectin, closely correlated with rate of softening of the fruit. A temperature of 32° F. greatly retarded the rate of soluble pectin formation.

15. Respiration intensity of peaches held at packing house temperatures (60 to 80° F.) rose very rapidly reaching its peak about a day after picking.

16. Respiration rates of approximately 4 cc. CO_2 per kilogram of fruit per hour at 32° F. were in sharp contrast to respiration rates ranging up to 47 cc. for peaches held at 60 to 80° F.

17. Delayed cold storage peaches, once they were chilled to 32° F. respired at a similar rate to peaches stored immediately at 32° F.

18. Immature and mature peaches respired at similar rates.

19. Storage of Rochester and J. H. Hale peaches in atmospheres containing 7 and 9% of carbon dioxide at 32° F. did not lengthen storage life, and in the case of Rochester resulted in skin injury.

ACKNOWLEDGMENT

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RATES OF GROWTH OF BACON-TYPE NURSING PIGS

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Animal growth data have numerous uses, not the least of which is that of serving as standards against which to gauge the results of management and feeding practice. There exists, however, a dearth of published data relative to growth of nursing pigs from which growth curves might be constructed. Ittner and Hughes (2), and Russel (3) have published curves for the growth of nursing pigs, curves which do not differ significantly from each other. Their data are based on lard type hogs where average litter size as well as nursing capacity of the sow may differ markedly from that of the bacon hog produced in Canada. No data appear to have been published for bacon type pigs.

Arrangements were made in 1940 to record weekly live weights of the nursing pigs in the swine herd at Macdonald College. Data suitable for the preparation of growth curves were then obtained from some 140 nursing pigs.

SOURCE AND NATURE OF THE DATA

The pigs used in this study were Yorkshires of Macdonald College breeding. They were the progeny of two different boars mated with sows related to one another as mother and daughter, full-sisters or half-sisters. One-half of the litters were farrowed in January and the other half in May. The male pigs were castrated at 4 weeks of age; and all pigs were weaned between the ages of 56 and 58 days.

The management and feeding of the sows was that generally practised at Macdonald College. The sows' feed consisted of barley, or barley 2 parts and wheat screenings 1 part, plus a protein-mineral supplement. No milk was fed at any time. During pregnancy the meal mixture consisted of 90 parts basal feeds and 10 parts protein-mineral supplement. It was changed to 85 parts basal feeds and 15 parts supplement following parturition. This gave rations of approximately 12 and 17% total protein respectively. The protein-mineral supplement was made up of meat meal, fish meal, linseed oilmeal, bone char, limestone, salt, iron and iodine. Sufficient cod liver oil was fed throughout the pregnancy and nursing periods to supply daily approximately 30,000 and 6,000 I.U. of vitamins A and D respectively.

Creep feeding of the young pigs was not practised, but the lactating sows were full fed 3 times a day to give the young pigs an opportunity to steal some of the feed from the trough.

The pigs were weighed at birth before being allowed to nurse, and each Tuesday thereafter until weaned. Thus the age of the pigs on any weigh day ranged from 3 days younger to 3 days older than the mean age of the group. No weights were taken between birth and the third day.

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PREPARATION OF THE GROWTH CURVE

In the construction of the growth curve (Figure 1) the individual weights recorded were collected into weekly age groups with the 7th, 14th, 21st, etc., days as the mid-points. Thus for example all weights of pigs between 10 and 17 days of age were put into the 14-day group. It may be mentioned at this point that no sex differences were found in any of these data when analysed by Fisher's (1) method of testing for significance of differences. Accordingly, the mean live weights for all pigs in each age group, irrespective of sex, were plotted against age, the curve being smoothed by fitting a second degree polynomial to the weight data. (Fisher's Summation Method (1).)

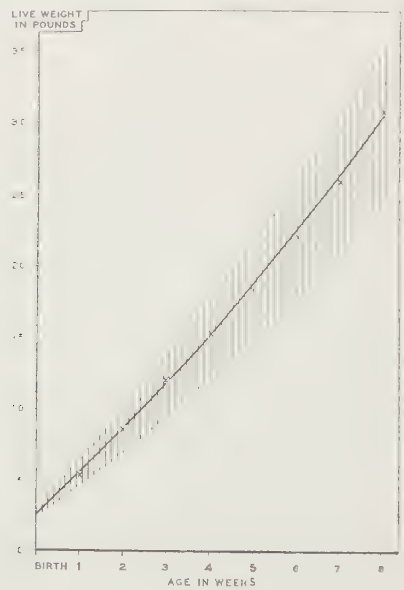

FIGURE 1. Live weights of Yorkshire pigs from birth to 8 weeks of age. Shaded area marks limits of ± one standard deviation about the mean.

RATE OF GAIN IN LIVE WEIGHT

In considering rate of gain as distinct from live weight attained at some specific age, two grouping systems may be employed for the data. The one, rate of gain at a given age, indicates the effects of increasing maturity on the growth of the animal. The other grouping, rate of gain at a given live weight, is often especially useful when feed efficiency is under consideration.

A grouping of the daily gains according to age is given in Appendix Table 2. Graphically, they are shown in Figure 2.

In arranging the data for this curve, the rate of gain for each pig was calculated as the average daily live weight increase between adjacent weighings. The values thus obtained were then applied to the age mid-way between the same two weighings.

The plotting data were smoothed by a third degree polynomial.

In grouping the gains according to attained live weight, the values for daily gain calculated for the gain-by-age curve were now applied to the weight midway between adjacent weighings instead of to the mid-age

FIGURE 2. Average daily gain of Yorkshire pigs from birth to 8 weeks old according to age. Shaded area marks limits of ± one standard deviation about the mean.

between these points. Plotting points above 33 pounds were not used because the number of observations were deemed too few to have any significance.

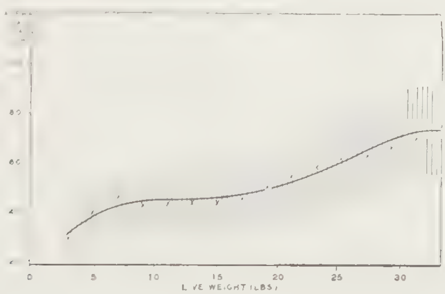

FIGURE 3. Average daily gain of Yorkshire pigs from birth to 8 weeks of age according to weight. Shaded area marks limits of ± one standard deviation about the mean.

The data are given in Appendix Table 3 and the curve, smoothed by fitting fourth degree polynomials, is shown as Figure 3.

SUMMARY

Data are presented of growth of Yorkshire pigs from birth to 8 weeks of age.

Three curves have been constructed as indices of normal growth rates of nursing Yorkshire pigs:

1. Live weight at specific age(s).
2. Rate of gain at specific age(s).
3. Rate of gain at specific weight(s).

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APPENDIX

Appendix Table 1.—Average live weight of Yorkshire pigs from birth to 8 weeks of age

Age of pigs (weeks)	Average live weight (lb.)	
	Observed values	Polynomial values
Birth	2.7 ± 0.4	2.7 ± 0.4
1	5.3 ± 1.4	5.5 ± 1.1
2	8.5 ± 1.8	8.4 ± 1.8
3	11.9 ± 2.3	11.6 ± 2.4
4	15.1 ± 2.9	14.9 ± 3.1
5	18.3 ± 3.7	18.4 ± 3.8
6	21.9 ± 4.5	22.2 ± 4.4
7	25.8 ± 4.9	26.1 ± 5.1
8	30.5 ± 6.1	30.2 ± 5.8

Appendix Table 2.—Average daily gain of Yorkshire nursing pigs

Weeks	Age range (day)	Average daily gains (lb.)	
		Observed values	Polynomial values
1	4 – 10	0.42 ± 0.11	0.43 ± 0.10
2	11 – 17	0.46 ± 0.12	0.45 ± 0.12
3	18 – 24	0.47 ± 0.13	0.46 ± 0.14
4	25 – 31	0.45 ± 0.17	0.47 ± 0.16
5	32 – 38	0.48 ± 0.16	0.48 ± 0.18
6	39 – 45	0.53 ± 0.19	0.52 ± 0.20
7	46 – 52	0.61 ± 0.21	0.60 ± 0.22
8*	53 – 59	0.73 ± 0.29	0.73 ± 0.24

* Incomplete as most pigs were weaned on 56th day. Rate of gain for 8th week calculated only for 90 pigs which remained at least 5 days in this period.

Appendix Table 3.—Average daily gains of Yorkshire pigs from birth to 8 weeks of age according to weight

Weight classes (lb.)	Average daily gain (lb.)	
	Observed values	Polynomial values
3	0.30 ± 0.07	0.32 ± 0.07
5	0.41 ± 0.11	0.39 ± 0.10
7	0.47 ± 0.09	0.43 ± 0.12
9	0.44 ± 0.14	0.45 ± 0.13
11	0.45 ± 0.14	0.46 ± 0.14
13	0.45 ± 0.15	0.46 ± 0.14
15	0.45 ± 0.15	0.47 ± 0.14
17	0.47 ± 0.15	0.48 ± 0.15
19	0.51 ± 0.15	0.50 ± 0.15
21	0.56 ± 0.14	0.54 ± 0.15
23	0.60 ± 0.15	0.57 ± 0.16
25	0.63 ± 0.16	0.62 ± 0.16
27	0.65 ± 0.18	0.66 ± 0.17
29	0.68 ± 0.18	0.71 ± 0.18
31	0.72 ± 0.18	0.73 ± 0.18
33	0.76 ± 0.18	0.74 ± 0.18

DISTRIBUTION OF *FLAVOBACTERIUM MALOLORIS*[1]

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[Received for publication June 8, 1943]

Flavobacterium maloloris was recently described and named by Wolochow *et al.* (3) who isolated 5 cultures of the organism from the water supply of an Alberta creamery. They showed that the bacterium is a causal agent of surface taint in butter, and expressed the opinion that it probably occurs so infrequently in creamery waters as to constitute only a minor factor in commercial surface taint.

The same authors identified as *F. maloloris* 2 cultures supplied to them by Dr. B. W. Hammer, Ames, Iowa, who encountered the organism infrequently in Iowa studies of putrid butter.

The purpose of the present study was to determine the distribution of this species in Alberta waters.

METHODS

The waters were plated on tryptone-glucose-extract-2% skimmilk agar and on nutrient gelatine. The gelatine plates were incubated at 10° C. to 15° C., while room temperature was used for the incubation of the agar plates. After incubation, varying from 3 to 5 days, yellow colonies were fished onto nutrient agar slants. For the determination of Duclaux constants the apparatus and technique of Dunkley (1) and Dunkley *et al.* (2) were employed.

RESULTS

One-hundred-and-forty waters from sources as set forth in Table 1 were obtained from the Provincial Laboratory and the Provincial Dairy Analyst. These yielded 561 cultures of yellow bacteria while 28 additional

Table 1.—Sources of water samples

Source	Number of samples
Cities	20
Towns	54
Lakes and rivers	25
War Service Training Centres	16
Unknown	25

cultures were received from students in courses in Dairy Bacteriology. Of these 589 cultures, 239 were gram-negative rods and 11 were gram-variable rods.

[1] These data are taken from a thesis submitted by the senior author to the University of Alberta in partial fulfilment of the requirements for the degree of Master of Science.
[2] Graduate student, Department of Dairying.
[3] Professor of Dairying.

Of the 250 cultures of gram-negative and gram-variable rods, only 23 peptonized litmus milk in the manner characteristic of *F. maloloris* as described by Wolochow *et al.* Each of 21 of these 23 cultures differed from *F. maloloris* by at least two important characteristics (Table 2) and none of the 21 cultures produced the sweaty feet odour in litmus milk.

TABLE 2.—DIFFERENTIATION OF 21 PROTEOLYTIC CULTURES AND *F. Maloloris*

Culture	Growth on T.G.E.M. agar	Motility	Nitrate reduction	Gelatine liquefaction	Indole production	Citrate carbon utilization	Starch hydrolysis	Methyl red test	Voges Proskauer reaction
F. maloloris		–	–	+	+	–	+	–	–
4	S	+	–	+	–	–	–	+	+
36	S	+	+	+	–	–	+	–	–
83a	D	–	+	+	–	+	+	+	–
93a	D	+	–	+	–	+	–		–
96, 96a	D	+	+	+	–	–	+	–	–
111a	D	+	–	–	–	+	+	+	–
109, 190a, 192a	S	–	+	+	–	–	+	–	–
197a	S	–	+	–	–	–	–		–
199	D	–	–	+	–	+	–	–	–
244	D	–	+	+	+	+	+	–	–
194, 207a, 227	D	+	–	+	–	–	+	+	+
58	D	+	+	+	+	+	–	–	–
19, 136, 217	S	–	–	+	–	+	+	+	–
146	S	+	–	+	–	+	+	–	–

S = Similar.
D = Dissimilar.

Two of the 23 cultures conformed in all respects to the original description of *F. maloloris* and, moreover, they produced the sweaty feet odour in litmus milk and surface taint in butter churned from high-temperature pasteurized, inoculated cream. One culture was isolated from a well water while the other was from a water of unknown source.

Some Further Characteristics of F. maloloris

Wolochow *et al.* found no definite utilization by *F. maloloris* of glucose, sucrose, lactose, or maltose as measured by colour changes in pH indicators. This list of carbohydrates may now be extended to include galactose, mannose, rhamnose, arabinose, xylose, raffinose, mannite and dextrin. The organism did not grow in Koser's citrate medium and lipolysis could not be demonstrated. Duclaux constants indicated the presence of acetic, butyric and isovaleric acids in "steam-distillate residues" from skimmilk cultures of the organism. These are the same volatile acids recognized by Dunkley *et al.* in "steam-distillate residues" from skimmilk cultures of *Pseudomonas putrefaciens*.

DISCUSSION

Since ability to produce yellow growth on common laboratory media was the criterion for isolation and subsequent recognition of *F. maloloris*, it may be that non-pigmented strains were missed. However, in the 9 cultures of the organism which have been studied in this laboratory, chromo-

genesis has been markedly persistent. Non-pigmented growth of any of these strains has not been observed on any solid medium. The criterion of isolation used by Wolochow *et al.* was not pigment but odour production in litmus milk. By these two methods only 7 strains from 3 water supplies have been encountered. If *F. maloloris* occurs frequently in Alberta waters, it appears necessary to assume the existence of strains which are non-pigmented and do not produce the typical odour in litmus milk. Inasmuch as the organism has been encountered and recognized so infrequently in both Alberta and Iowa, there appears to be justification for the opinion expressed by Wolochow *et al.* that *F. maloloris* is less important than *P. putrefaciens* in commercial surface taint in Alberta.

SUMMARY

Only 2 cultures of *F. maloloris* were encountered among 589 isolations of yellow bacteria from 140 Alberta waters. This supports the view that this organism is less important than *P. putrefaciens* as a cause of commercial surface taint in Alberta.

Duclaux constants of steam-distillate residues of skimmilk cultures of *F. maloloris* indicated the same volatile acids as previously reported for *P. putrefaciens*, i.e., acetic, butyric, and isovaleric acids.

ACKNOWLEDGMENTS

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THE EFFECT OF ALKALI WATER ON BONE STRENGTH IN RATS[1]

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In many sections of the Prairie Provinces the water for live stock comes from wells and is alkaline in nature. The long continued use of water high in glauber and epsom salts has often been suspected of having injurious effects on live stock though experimental evidence has been lacking. This paper presents the results of experiments in which rats were used to determine the effects of "representative" alkali waters on bone strength.

MATERIAL AND METHODS

Analyses of well water samples have shown considerable variation but the majority of high alkali samples were very similar in composition. The salts most commonly present were sodium sulphate or glauber salts (Na_2SO_4), magnesium sulphate or epsom salts ($MgSO_4$), calcium sulphate or gypsum ($CaSO_4$), sodium bicarbonate ($NaHCO_3$), and sodium chloride or common salt (NaCl).

Saskatoon tap water, which has a negligible content of solids, was chosen as the control treatment. Two other treatments were made up by dissolving sufficient salts in tap water to simulate representative samples from Saskatchewan wells. "Medium" alkali water with a total solid content of 0.75% was produced by adding 0.55% Na_2SO_4, 0.13% $MgSO_4$ and 0.07% $NaHCO_3$. The water designated as "strong" alkali was made up to 1.4% total solids by adding 1% Na_2SO_4, 0.25% $MgSO_4$ and 0.15% $NaHCO_3$.

A breeding colony of albino rats of unknown history was maintained for the purpose of producing experimental animals. In the experiment only 3 animals of one sex or 3 of each sex were used from any one litter. At weaning time these were distributed between the treatments. Group I received tap water, Group II medium alkali water, and Group III strong alkali water.

All of the animals received a standard ration made up as follows:

Ground wheat	30 lb.
Ground barley	20
Ground corn	20
Meat meal	10
Bone meal	4
Skim milk powder	8
Fish meal	5
Brewer's yeast	2
Common salt	.5
Cod liver oil	.5
Total	100 lb.

[1] Contribution from the Animal Husbandry Department, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

[2] Professor of Animal Husbandry.

[3] Instructor in Animal Husbandry.

[4] Instructor in Animal Husbandry.

Bone strength was determined by means of a simple device consisting of two pieces of $\frac{7}{8}'' \times \frac{1}{8}''$ strap iron. One piece 8″ in length was bent in the shape of a clevis, the free ends being just far enough apart to allow the second piece to slide freely. A $\frac{5}{16}''$ hole was drilled through both arms of the clevis about one inch from the ends. A similar hole was drilled near one end of the sliding piece.

The clevis end of the instrument was clamped to a table and the sliding part to a beam scale. To determine bone strength the femur was inserted through the holes and weight applied to the scale until breaking occurred. Both femurs were used for each rat and the breaking weights averaged. The 2 femurs from a single rat usually broke at the same weight and in no case was there a wide variation.

Total ash was determined by placing the entire bodies, without loss of blood or other tissue, in electric furnaces at 700° C. until a constant temperature was achieved. This required approximately 9 hours. Like sex litter mates, 1 from each of the 3 treatment groups were cremated simultaneously.

RESULTS

Bone Breaking Tests

There was no significant difference between the control and medium alkali treatments as shown in Table 1.

TABLE 1.—THE EFFECT OF ALKALI WATER ON BONE STRENGTH IN RATS

	No. of animals		Av. age in days		Av. bone break in lb.		
	Male	Female	Male	Female	Male	Female	Male and Female
Group I Control	9	6	101.3	100.5	36.1	30.4	33.8
Group II Medium Alkali	9	6	101.3	100.5	35.8	31.0	33.9
Group III Strong Alkali	9	6	101.3	100.5	30.9	27.9	29.7
	27	18					32.5

The difference between medium and strong alkali treatments was statistically significant as indicated by the following analysis of variance (Table 2) It is also apparent that the significant difference between sexes was independent of treatment. The larger size of the femurs of males is believed to be largely responsible for their greater strength.

TABLE 2.—ANALYSIS OF VARIANCE OF BONE BREAKING WEIGHTS FOR RATS

Source of variation	D.F.	Sum of squares	Mean square
Between treatments	2	173.6	86.80*
Between sexes	1	218.7	218.70*
Treatment × sex	2	13.9	6.95
Within subclasses	39	755.3	19.37
Total	44	1,161.5	

* Significant at the 1% level.

Total Ash

No significant differences between groups in total ash content was found as indicated in Table 3.

TABLE 3.—THE EFFECT OF ALKALI WATER ON TOTAL ASH CONTENT OF RATS

	No. of animals		Av. age in days		Av. ash content in per cent		
	Male	Female	Male	Female	Male	Female	Male and Female
Group I Control	9	6	101.3	100.5	3.44	3.94	3.62
Group II Medium alkali	9	6	101.3	100.5	3.34	3.95	3.57
Group III Strong alkali	9	6	101.3	100.5	3.38	3.85	3.56

Other Factors

Although this paper is primarily concerned with the effect of alkali water on bone strength in rats some additional data of a preliminary nature were gathered. The rate of growth of the rats was determined by weekly individual weighings from weaning time until the rats were killed and the results are summarized in the following table. It was observed that the rats on alkali water made the poorest gains just after weaning at which time they were least tolerant to the purging effect of the salts.

TABLE 4.—THE EFFECT OF ALKALI WATER ON WEIGHTS AND RATES OF GAIN

	No. of animals		Av. wt at 100 days		Av. daily gain		
	Male	Female	Male	Female	Male	Female	Male and Female
			Gm.	Gm.	Gm.	Gm.	Gm.
Group I Control	8	6	220	156	2.2	1.5	1.9
Group II Medium alkali	8	5	200	154	2.0	1.5	1.82
Group III Strong alkali	7	6	186	145	1.8	1.4	1.67

During the latter part of the experiment the breeding pens were placed on the 3 treatments and the subsequent breeding performance suggested a detrimental effect of alkali water on fertility.

		No. of females	Litters born
Group I	Control	11	24
Group II	Medium Alkali	11	21
Group III	Strong Alkali	11	12

The presence of infection in the colony at a late stage in the trial resulted in a high degree of sterility and thus introduced a new variable.

Histological examination of the thyroid glands of rats from the 3 groups failed to indicate any abnormality. This would indicate that lack of vitamin E absorption was not responsible for the lowered fertility since lack of vitamin E causes a definite hypoactivity of the thyroid.

DISCUSSION

The results of the present investigation indicate that alkali salts must be regarded as a nutritional handicap. This suggests a problem which has assumed considerable importance in the Prairie Provinces. Feeders in some instances have been persuaded to use a crystalline salt product recovered from prairie lakes and sloughs instead of common salt in rationing live stock. This product represents the crystallized form of certain salts present in the water and in most cases the range of salts and their proportions are very similar to those found in the majority of wells. In any case glauber salts predominate and common salt is only present in very small amounts. Glauber and epsom salts, as stockmen know, have certain medicinal properties and can be administered as cathartics, but they will not take the place of common salt in practical live stock rations in this country.

SUMMARY

Bone strength in rats on salt free, medium alkali, and strong alkali waters was determined by means of a shear test. Significant differences between treatments were found indicating that alkali water has a harmful effect on bone development. There was no significant difference between groups in total ash content of the bodies. Rats on alkali water made slower gains than the control group and fertility was impaired.

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THE ROLE OF INSECTS, WEATHER CONDITIONS, AND PLANT CHARACTER IN SEED SETTING OF ALFALFA[1]

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Seed production of alfalfa, in contrast to forage production, is confined to relatively isolated localities. In addition, maximum yields are secured in these localities only in exceptionally favourable years. Saskatchewan in recent years has been one of the main alfalfa seed producing provinces of Canada, with her production concentrated on the grey bush soils of northern areas. Seed production in northern Saskatchewan began in the White Fox district about 1932, and the industry developed at a phenomenal rate on account of the high yields obtained, and the suitability of the alfalfa seed enterprise to poorly equipped farms of this frontier area. There have been, however, several years of failure due to poor seed setting, early fall frosts, and winter killing.

As a result of the increasing importance of the alfalfa seed industry in Saskatchewan and successive seed failures, a series of seed setting studies was conducted at Saskatoon from 1939 to 1942, and at White Fox in 1941 and 1942. The main objectives have been to determine the relation of tripping to seed setting and factors responsible for tripping, and to investigate the possibility of breeding reliable high seed setting strains.

LITERATURE REVIEW

The tripping process found in the alfalfa flower was fully described by Piper *et al.* (11). The necessity of tripping for pod setting was shown by them and by Armstrong and White (2), Tysdal (14), and several other investigators. Carlson (5), and Brink and Cooper (3) reported considerable seed setting from untripped flowers.

Piper *et al.* (11) in 1914, and Aicher (1) in 1917, pointed out the value of leaf-cutter, or *Megachile* bees, in seed setting areas of the United States. However, they considered that good seed setting would take place without these insects. Sladen (13) found leaf-cutter bees of the species *Megachile latimanus* Ckll. in seed areas of Alberta, and observed them tripping flowers at the rate of 17 per minute. Salt (12) gave recommendations for the utilization of wild bees in seed production in Western Canada. Tysdal (14), in 1940, reported extensive investigations of seed setting in the United States. Leaf-cutter bees (*Megachile* spp.) and alkali bees (*Nomia* spp.) were found to be responsible for most of the tripping and pollination of alfalfa flowers. From direct observation of marked flowers these species were found to trip more than 4 times as many flowers as all other insects combined. In Nebraska *Megachile* species were important, and in the Western States *Nomia* species were common. In Eastern States bumble bees were the chief tripping agent. Honey bees were observed to trip only 1.1% of the flowers visited.

[1] Contribution from the Dominion Forage Crops Laboratory, Saskatoon, Sask., being a condensation of a thesis submitted to the Graduate School of the University of Saskatchewan in partial fulfilment of the requirements for the Degree of Master of Science.

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Reduced seed setting from caging alfalfa was reported by Piper *et al.*, Dwyer and Allman (7), Hadfield and Calder (9), and Lejeune and Olson (10). Dwyer and Allman were able to restore seed setting under cages by introducing large numbers of honey bees. Hadfield and Calder obtained good seed setting under cages by using bumble bees but found honey bees of relatively little value.

Aicher (1) pointed out the value of having alfalfa seed fields come into flower during the hottest and driest part of the season, when bee activity was greatest. Carlson (5) found low relative humidities, with frequent fluctuations, to be associated with good seed setting in Utah. Englebert (8) showed that excessive rainfall during July reduced seed yields in Ontario. Tysdal (14) found temperature to play a very important rôle in insect activity and alfalfa tripping. The amount of *Megachile* visitation and alfalfa tripping were higher during the hotter periods of the day, that is from 1 to 4 p.m.

Burkhart (4) found 84.5% cross-fertilization taking place on the average in Argentina. Tysdal *et al.* (15) reported 89.1% natural crossing. Increases in seed setting following cross-pollination as against self-pollination were shown by Piper *et al.* (11), Hadfield and Calder (9), Cooper and Brink (6), and Tysdal (14). Cooper and Brink found that cross-pollination of inbred plants gave 4.5 seeds per flower whereas self-pollination gave 0.8 seeds per flower. They described the inferior seed setting following self-pollination as being due to partial self-incompatibility and to the abortion of many self-fertilized embryos.

MATERIALS AND METHODS

Throughout most of these investigations a detailed type of study was used in which the individual alfalfa flower was made the unit of observation. Racemes to be studied were reduced to about 8 buds whose relative positions upon the flowering axis indicated their identity. Individual flower histories were made in which the dates of opening, tripping, and wilting of each flower were recorded. In addition, the abscission of the flower or its development into a pod, together with the number of seeds per pod were noted. It was thus possible to relate seed setting to very definite methods of flower development and weather conditions existing at flowering time. A study of this type also allows a critical comparison of plants with regard to tripping and seed setting behaviour. Observations of marked flowers were made once a day between the hours of 7 a.m. and 9 a.m. though in some studies flowers were examined every 4 hours from 4 a.m. to 8 p.m. Meteorological data were obtained from the Physics Department of the University of Saskatchewan and from thermohygrograph records near the site of flower observations.

The rôle of large tripping insects was studied by using screen cages to exclude them, the difference in plant performance inside and outside cages then being attributed to insect action. A cage 2 feet square, 2 feet high, and constructed of ordinary window screening was used most commonly in caging studies. This cage was built so that it could be opened quickly, and the enclosed flowers examined readily. Only half of any plant was

caged so as to allow a comparison of seed setting of caged and uncaged flowers on the same plant basis. To localize caging effect on the plant a small type of cage was constructed which could be placed over an individual flowering raceme. These small raceme cages gave results comparable to those of large cages. To study the effects of shading, raceme cages of various wire weights were applied to the same plants. Quite large screen cages were used in the White Fox area in 1941 and 1942 to find the effects of caging in solid stands.

The importance of various bees was also found by observing their abundance in alfalfa fields, their periods and rates of operation, and seeds formed from flowers which they tripped. In estimating bee populations in any field the method adopted was to count the bees in 20 random circular areas, each of a diameter of about 6 feet. No attempt was made to make this count represent the whole field. Frequently counts were made over an area 200 yards across at one end or one side of a field. Observations of tripping and seed setting for fields were confined to the area used in making bee counts. Making bee counts in this manner was found to give a more reliable index of bee populations than the method of making sweeps and, in addition, determinations could be made quickly.

Tests of seed setting following self- and cross-pollination were made without emasculation. Self-pollination was accomplished simply by tripping a flower with a clean toothpick so that the staminal column struck the toothpick squarely. Cross-pollination was performed by similarly tripping a flower with a toothpick bearing foreign pollen. Five flowers were cross-pollinated before renewing the toothpick. In all cross-pollinations a group of 10 random Grimm plants was used to provide a source of mixed pollen. Only fresh flowers were used in pollination studies, and foreign pollen was excluded by the use of Kraft and glassine paper bags.

At Saskatoon, observations were made on spaced plants, the spacing in most cases being 1 foot by 3 feet. At White Fox, all plants observed were growing in solid stands. Studies were confined mainly to random open-pollinated Grimm plants. Where inbred plants were used this has been indicated. A group of high seed setting selections made from poor seed fields at White Fox and at Saskatoon, and which had maintained their good seed setting habits under greenhouse conditions, were also included.

Typically low seed yields were obtained at Saskatoon in 1939 and 1940. In the very dry year 1941, however, exceptionally high seed yields were secured, especially on second growth material in flower during August. At White Fox in 1941, yields were high, several fields yielding over 400 pounds of seed to the acre. The extremely wet season in 1942 did not favour seed setting at Saskatoon or at White Fox.

OBSERVATIONS

The Relation of Tripping to Seed Setting

Before discussing the effects of caging on seed setting an understanding of seed setting under open-pollination is desirable. A summary of tripping and seed setting data from all uncaged flowers studied in detail from 1939 to 1942 is given in Table 1.

TABLE 1.—TRIPPING AND SEED SETTING IN ALFALFA AS DETERMINED FROM INDIVIDUAL FLOWER HISTORIES, *1939-1942*

Selection	Plants observed	Flowers observed	Tripping	Tripped flowers setting pods	Non-tripped flowers setting pods	Seed formed	
						Per pod set	Per flower observed
	no.	no.	%	%	%	no.	no.
1939—Saskatoon							
High seed setting	8	249	53.3	59.5	1.6	—	—
Winter hardy	6	173	21.3	28.9	3.6	—	—
Seed setting without tripping	6	180	44.4	36.2	17.0	—	—
M. falcata	6	102	23.5	16.7	1.3	—	—
Total and Av. (weighted) for strains	26	709	38.9	47.1	5.8	—	—
1940—Saskatoon							
High seed setting	7	263	55.9	61.9	6.9	2.6	0.93
Winter hardy	5	183	25.1	34.8	0.7	1.2	0.11
Seed setting without tripping	2	78	46.2	44.4	0.0	0.9	0.19
White-flower	4	159	51.6	52.4	0.0	2.6	0.70
Check—Grimm	12	507	53.6	62.5	1.3	3.3	1.10
Total and Av. (weighted) for strains	30	1190	49.0	57.6	2.0	2.8	0.80
1941—Saskatoon							
High seed setting	3	233	72.1	75.0	0.0	3.0	1.65
White-flower	2	88	30.7	14.8	0.0	1.8	0.08
Check Grimm—first growth	16	996	59.3	52.4	0.1	3.0	0.92
Check Grimm—second growth	25	606	69.6	53.6	0.2	3.3	1.23
Total and Av. (weighted) for strains	46	1923	62.8	55.1	0.1	3.1	1.07
1942—White Fox							
Random Grimm	40	1320	32.5	40.1	0.1	3.8	0.50
Total and Av. (weighted) years 1940-1942	116	4433	50.1	52.9	0.7	3.1	0.82

Since most of these observations were made under rather unfavourable conditions for seed setting, Table 1 should be examined with a view to finding the causes of seed failure. The 3-year average indicates that approximately half of the flowers failed to trip and of these untripped flowers only 0.7% set pods. Tripping is thus shown to be almost an obligatory requisite to pod formation. Piper *et al.* (11), Armstrong and White (2), and Tysdal (14) also found little pod setting from untripped flowers. Of the flowers which did trip 52.9% set pods, and these pods contained an average of 3.1 seeds. As a result of partial tripping, partial pod setting, and incomplete pod filling only 0.82 seeds per flower were obtained on the average. Considering that alfalfa flowers have been shown by Cooper and Brink (6) to contain 12 to 14 ovules, it would appear that in these studies less than 10% of the full plant fertility was being realized.

The high seed setting selections generally showed higher seed setting than the other materials. A fuller description of these plants will be given in a later section. The inbred material selected for seed setting without tripping shows considerable pod setting from untripped flowers in 1939, but not in 1940. The winter hardy selections, which were inbred, and the white-flower, and *Medicago falcata* materials show somewhat more severe reductions in tripping, pod setting, and number of seeds per pod than does the Grimm material.

Caging Treatments

In 1941 and 1942, detailed studies of the effects of caging were carried out at Saskatoon and at White Fox. At Saskatoon the 2-foot square cage was used, while at White Fox raceme cages were employed. Table 2 gives a summary of seed setting of caged flowers and corresponding uncaged check flowers on the same plants.

TABLE 2.—TRIPPING AND SEED SETTING OF CAGED ALFALFA FLOWERS AND CORRESPONDING UNCAGED CHECK FLOWERS, 1941-1942

Strain	Plants observed	Flowers observed	Tripping	Tripped flowers setting pods	Seeds formed	
					Per pod set	Per flower observed
	no.	no.	%	%	no.	no.
CAGED FLOWERS						
1941—Saskatoon						
1. Selections—high seed setting	3	244	58.1	53.5	1.8	0.56
2. Selections—white flower	2	71	19.7	7.1	0.0	0.00
3. Check Grimm—First growth	16	1007	24.9	23.1	1.3	0.08
4. Check Grimm—Second growth	25	603	19.1	24.3	1.5	0.07
1942—White Fox						
5. Check Grimm	20	713	23.0	19.4	1.9	0.08
Total and Av. (weighted)	66	2641	26.0	28.4	1.6	0.11
UNCAGED FLOWERS						
1941—Saskatoon						
1. Selections—high seed setting	3	233	72.1	75.0	3.0	1.65
2. Selections—white flower	2	88	30.7	14.8	1.8	0.08
3. Check Grimm—first growth	16	996	59.3	52.4	3.0	0.92
4. Check Grimm—second growth	25	606	69.6	53.6	3.3	1.23
1942—White Fox						
5. Check Grimm	20	738	35.5	37.4	3.6	0.48
Total and Av. (weighted)	66	2661	55.4	51.8	3.2	0.90

From Table 2 it is apparent that caging alfalfa flowers seriously interferes with tripping, pod setting, and pod filling. The average number of seeds per caged flower was only 0.11 as against an average of 0.90 seeds per uncaged flower. Only the high seed setting selections set appreciable seed under cages. White flowered plants set seed poorly under all conditions.

Large screen cages were also erected in fields near White Fox in 1941 and 1942 to find the reduction in seed setting of solid stands following caging. These cages were erected at the beginning of the flowering season and removed at harvest time. Seed production within cages was compared with that of duplicate uncaged areas adjacent to the cages. In 1942, an

FIGURE 1. The caging arrangement used in a field of the White Fox district in 1942. Canvas canopy on the left, screen cage on the right.

additional treatment was given in the form of a canvas canopy, the object being to provide excess shading and yet allow insect visitation. A typical arrangement of cages is shown in Figure 1. The seed yields for all caged and comparable uncaged check areas is given in Table 3.

TABLE 3.—SEED YIELDS OF ALFALFA UNDER LARGE SCREEN CAGES, CANVAS SHADES, AND NATURAL FIELD CONDITIONS

Location	Area	Seed yields in lb. per acre		
		Screen cage	Canvas shade	Average of 2 check areas
1941—White Fox				
A	5′ × 4′	74	—	407
B	5′ × 4′	50	—	106
Total A and B		124		513
% of check		24.2		100
1942—White Fox				
A	6′ × 6′	9	26	41
C	6′ × 6′	12	22	58
D	5′ × 4′	93*	—	73
E	5′ × 4′	28	—	44
Total A, C, E,		49		143
% of check		34.3	—	100
Total A, C		21	48	99
% of check		21.2	48.5	100

* Six *Megachile* bees trapped in cage.

Unfortunately cages were erected a little late, and as a result some flowering took place before insects were excluded. In addition, seed yields in 1942 were low in all fields where cages were erected. Seed yields under cages in 1941 were, on the average, only 24.2% of those of uncaged check areas. The yields of areas A and B under cages were similar but outside the cages area A far outyielded B. Despite the low yields obtained in 1942 the average yield of caged areas at A, C, and E was only 34.3% of check uncaged alfalfa. The results of location D were not included in the above average as 6 *Megachile* bees were found trapped within the cage a few weeks after it was erected. The fact that this cage alone gave yields exceeding those of check areas clearly demonstrates the ability of these insects to aid seed production.

Shaded areas gave yields intermediate between those of caged and check areas. The reduction in yields under canopies was attributed to the reluctance of wild bees to venture into the shade, rather than to any direct shading effects. Temperatures and humidities obtained from wet and dry bulb thermometers were found to vary but little under the 3 types of exposure.

Additional information regarding the effects of caging were obtained by enclosing racemes within cages giving different degrees of shading. If shading is a factor causing reduced seed yields then a differential reduction in seed setting should result from different intensities of shading. One type of raceme cage, termed here "single cage," consisted of a single thickness of window screen. A second type, termed "triple cage," consisted of 3 thicknesses of window screen. The third type of raceme cage was

FIGURE 2. Three types of raceme cages attached to an alfalfa plant. Left to right—check, fine cage, triple cage, single cage.

constructed of very fine wire. This "fine cage" gave practically negligible shading. In 1941 these 3 types of raceme cages were applied to the open halves of plants already caged with the 2-foot square cage so that the 4 methods of caging were compared on the same plants. In 1942 the study was repeated in the White Fox area in solid stands, but here the 2-foot square cage was not available. Figure 2 shows the 3 raceme cages attached

to a plant near White Fox. Seed production under the different cages is shown in Table 4.

Since practically the same number of flowers were used under all exposures, a comparison of caging treatments can be made directly from the number of seeds formed. Obviously in both years the 3 types of raceme

TABLE 4.—TRIPPING AND SEED SETTING OF ALFALFA FLOWERS UNDER LARGE SCREEN CAGES, THREE TYPES OF RACEME CAGES AND UNCAGED CONDITIONS

No. of plants	Caging treatment	No. of flowers observed	No. of flowers tripped	No. of pods set	No. of seeds set
	1941—Saskatoon				
18	Large 2′ cage	318	55	15	8
	Triple raceme cage	326	49	6	1
	Single raceme cage	324	39	6	2
	Fine raceme cage	320	90	20	20
	Check—uncaged	282	196	84	157
	1942—White Fox				
18	Triple raceme cage	168	50	10	22
	Single raceme cage	168	34	10	23
	Fine raceme cage	168	31	9	20
	Check—uncaged	168	81	45	175

cages were all affecting seed setting in a similar manner. The slight increase in seed setting under the fine cage in 1941 was attributed to faulty cage construction which was corrected in 1942. It is concluded that the slight effect which cages had on light intensity, temperature, humidity, and air movement within them had little or no influence on seed setting.

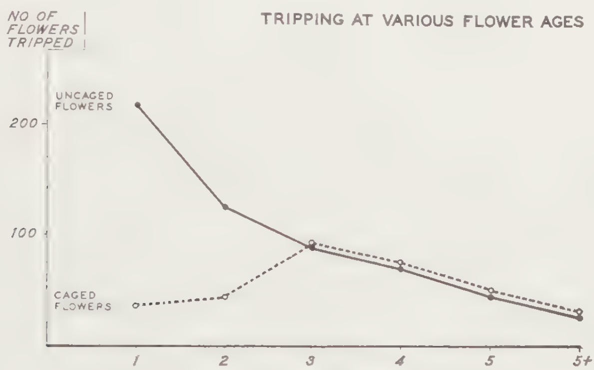
A comparison was made of caged and uncaged flowers in the number of days required for tripping to take place after flowers had opened. The flowers which tripped were listed according to flower age at tripping time. In addition, the number of seeds forming from flowers tripped at various dates was found. These data are presented graphically in Figure 3.

Under uncaged conditions most of the tripping occurred when flowers were 1 to 2 days old. Under caged conditions most of the tripping occurred when flowers were 3 or more days old. Seed setting was most favourable following the tripping of young uncaged flowers. It would appear that tripping under caged conditions is entirely different in nature from that occurring under open-pollination. Tripping under cages may be considered somewhat of a flower collapse which occasionally results in seed setting. Tripping under open-pollination is due largely to the activity of insects on fresh flowers, and results in good pollination and seed formation.

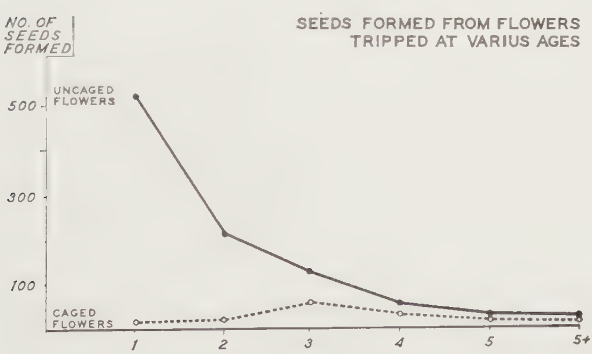
The Importance of Insects

The activity of wild bees of the leaf-cutter type was apparent from inspections of alfalfa fields in the White Fox area in 1941 and 1942. It appeared that the marked variation in seed yields between fields could be

explained by the relative abundance of leaf-cutter bees in these fields. Notes were made of fields visited with regard to seed setting, tripping and the abundance of bees, as well as stand and field characteristics. Instead of taking seed yields, fields were scored on the basis of 1 to 10 according to the amount of pod setting at the time of inspection during mid-flowering. The number of freshly tripped flowers on 20 random flowering racemes was used as an index of tripping. The method of counting the number of bees in 20 small areas, 6 feet across, has already been described. Field sizes were estimated, and the amounts of unbroken waste land surrounding fields were recorded in the form of scores. Care was taken to make observations between the hours of 10 a.m. and 5 p.m. when temperatures were over 70° F., so that bee activity could be observed.



AGE OF FLOWER IN DAYS WHEN TRIPPED.



AGE OF FLOWER IN DAYS WHEN TRIPPED.

FIGURE 3. The times of tripping for caged and uncaged alfalfa flowers and the effects on seed setting; (1243 caged and 1325 uncaged flowers studied in 1941 and 1942).

Megachile bees were not as common as honey bees but were more numerous than bumble bees. No counts were made of honey bees in 1941, but an average of 2.5 *Megachile* and an average of 0.6 bumble bees per 20 six-foot areas were found. In 1942 the average numbers of honey, bumble, and *Megachile* bees per 20 areas were 6.2, 1.6, and 0.1, respectively. The r values obtained in correlations of bee populations, seed

setting, and field characteristics are indicated in Table 5. Significant correlations indicate the closeness of the relationship between seed setting, tripping, and the number of *Megachile* bees. Bumble bees were not sufficiently numerous to permit separate correlations of their numbers and seed setting. It was thought that the correlation between the number of honey bees, and tripping and seed setting in 1942, was due to the attraction of honey bees and *Megachile* bees to the same fields. Fields surrounded by waste land showed better seed setting, in general, than those surrounded by cultivated fields. The highly significant correlation obtained between the amount of waste land and the number of *Megachile* and bumble bees may account for this relationship.

TABLE 5.—THE RELATIONSHIP OF SEED SETTING AND TRIPPING OF ALFALFA FIELDS IN THE WHITE FOX AREA TO BEE POPULATIONS AND FIELD CHARACTERISTICS 1941-1942

Factors considered	Value of *r*	
	1941 (49 fields)	1942 (67 fields)
Seed setting score—No. of *Megachile* and bumble bees	+ 0.70	+ 0.52
Seed setting score—No. of *Megachile* bees	+ 0.64	+ 0.53
Seed setting score—No. of honey bees	—	+ 0.28
Seed setting score—Amount of tripping	+ 0.54	+ 0.43
Seed setting score—Amount of adjacent waste land	+ 0.55	+ 0.39
Seed setting score—Size of field	− 0.15	+ 0.02
Amount of tripping—No. of *Megachile* and bumble bees	+ 0.62	+ 0.68
Amount of tripping—No. of *Megachile* bees	+ 0.58	+ 0.69
Amount of tripping—No. of honey bees	—	+ 0.54
Waste land—No. of *Megachile* and bumble bees	+ 0.53	+ 0.36
Size of field—No. of *Megachile* and bumble bees	+ 0.08	− 0.11
Value of *r* 5% point	0.29	0.25
Value of *r* 1% point	0.37	0.32

In 1942, preliminary studies were made of the value of *Megachile* bees as tripping and pollinating agents. Thirteen leaf-cutter bees were observed for their rate of flower visitation. The number of flowers visited per minute ranged from 10 to 32, with an average value of 17.3. It appeared that practically all flowers visited were tripped, but no actual counts of the efficiency of each bee were made. Bumble bees were also found to be efficient trippers but their numbers were very small in comparison with those of leaf-cutter bees. No counts were made of the efficiency of honey bees, but general observations throughout these studies emphasized their inability to trip alfalfa flowers. A comparison was made in early August in 1942 of the seed setting following hand tripping and seed setting following tripping by leaf-cutter bees. Racemes worked on by these insects were trimmed to tripping flowers and tagged. The same number of flowers on the same plants were hand tripped by applying pressure to the bases of flowers with tweezers. Table 6 gives the results of this comparison of natural and artificial tripping.

TABLE 6.—A COMPARISON OF SEED SETTING FOLLOWING THE TRIPPING OF ALFALFA FLOWERS BY *Megachile* BEES WITH THAT FOLLOWING THE ARTIFICIAL TRIPPING OF FLOWERS ON THE SAME PLANTS AT WHITE FOX, 1942

Location	Bee	No. of plants	Tripping of *Megachile* Bees			Hand Tripping		
			Flowers tripped	Seeds formed	Seeds per tripped flower	Flowers tripped	Seeds formed	Seeds per tripped flower
A	a	4	31	109	3.52	31	9	0.29
	b	3	19	57	3.00	19	2	0.10
B	c	2	4	22	5.50	4	5	1.25
	d	1	11	4	0.36	11	5	0.45
C	e	7	39	73	1.87	39	23	0.59
Total and Av.			104	265	2.55	104	44	0.42

The number of observations made are limited but it is apparent that flowers tripped by leaf-cutter bees set considerably more seed than those tripped by hand. As will be shown in a later section of this paper, cross-pollination results in much better seed setting than self-pollination. *Megachile* bees are especially adapted for cross-pollination by the pollen pad found on the lower abdominal surface. Undoubtedly the markedly higher seed setting resulting from tripping by leaf-cutter bees as contrasted to hand tripping is accounted for by the cross-pollination effected by the insects.

Assuming that flowers tripped by leaf-cutter bees set 2.55 seeds on the average, and that a bee trips 15 flowers per minute, then in 1 hour 1 bee would account for 2,250 seeds. Work at such a rate for 100 hours would result in about 1 pound of alfalfa seed.

The possibility that wind might be a vector of pollen and thus a factor in cross-pollination was considered. Studies of pollen dispersal by means of exposing and examining greased slides and of examinating flower standards indicated that wind was not an important vector of pollen. Insects must be relied upon to perform this important function.

No evidence of the nesting of leaf-cutter bees was found in alfalfa or other cultivated fields. However, the examination of uncleared land adjacent to alfalfa fields frequently revealed these bees in flight. They seemed to be attacted to certain stumps or logs. These bees were found making careful examinations of knot holes in logs of the balsam poplar (*Popylus tacamahacca* Mill.). An examination of such logs revealed empty tunnels and dead cells, but no fresh cells for the storage of pollen and nectar were found. Near such logs *Megachile* bees were quite docile and were frequently handled and examined. Their affinity for salty surfaces and small holes was shown on several occasions.

From general observation it appeared that the activity of leaf-cutter bees was influenced by weather conditions in much the same way as that of honey bees. They were occasionally found working at earlier periods of the day and at lower temperatures than honey bees. A study of the amount of tripping during various periods of day and at various seasonal periods, which will be discussed in a later section, gives indirect evidence of their period of activity.

Megachile bees were suspected of having marked flower preferences. This was indicated to a certain extent by the variation in seed setting between adjacent fields, between plants in any one location, and between early and later flowering racemes on the same plants. These bees were commonly observed to confine their work in any one small location to the tripping of flowers on 1 or 2 plants. It was thought that such plants were more attractive to bees because they possessed more suitable pollen and nectar. Improved yields from certain cultural practices may in turn depend on improved attractiveness of flowers to bees. In this connection it may be stated that *Megachile* bees were found more numerous in young vigorous stands. The preference of leaf-cutter bees for wild sources of flower was also clearly shown in the White Fox area in 1942. During early August little tripping of alfalfa was observed, even in fields formerly showing much tripping in July. Large amounts of perennial sowthistle (*Sonchus arvensis* L.), and fireweed (*Chamaenerion spicatum* Lam.) come into flower in early August, and an examination of these weeds showed *Megachile* bees working them in preference to adjacent alfalfa.

Of 20 leaf-cutter specimens collected in sweeps in alfalfa fields, and submitted to Dr. O. Peck, Division of Entomology, Dominion Department of Agriculture, Ottawa, for identification, the following species were found:

Megachile (*Delomegachile*) *vidua* Sm.	12 ♀ ♀
Megachile (*Anthemois*) *montivaga* Cress.	3 ♀ ♀
Megachile (*Xanthosarus*) *latimana* Say	2 ♀ ♀
Megachile (*Sayapsis*) *pugnata* Say	1 ♂
Megachile (*Chelostomides*) sp.	1 ♀
Megachilid, not *Megachile*	1 specimen

Females of the species *M. vidua* were the most common leaf-cutter in alfalfa fields. Several of these species, and an additional species *Megachile* (*Anthemois*) *inermis* Prov., were found on perennial sowthistle and fireweed. Practically all specimens collected were females; males were more commonly found upon stumps and logs.

The Effect of Weather Conditions

The effects of weather conditions on seed setting were studied by comparing meteorological data of 24-hour periods with the behaviour of alfalfa flower in blossom during the same time intervals. Since the dates of flower opening, tripping and wilting were available in flower histories, it was possible to find the number of fresh untripped flowers present on any day. The number of flowers which tripped on each day was then expressed as a percentage of fresh flowers under observation on that day. Records were available of the pods and seeds formed from all flowers tripped, so that it was possible to find which days were suitable for pollination as well as suitable for tripping. As data were available for caged and uncaged flowers the direct effects of weather conditions could be distinguished from the indirect effects of weather conditions on bee activity.

Populations of 100 to 200 fresh flowers were maintained as a rule under caged and uncaged conditions, but in 1940 the average flower population for caged conditions was only 18. The number of uncaged flowers

in 1940 also fluctuated widely so that a grouping of tripping and meteorological data for 5-day periods was made. The same plants were used throughout each season, except in 1941, when the severe summer drought made it necessary to use second-growth alfalfa during August. Figure 4 has been prepared to show the wide fluctuations and trends of tripping

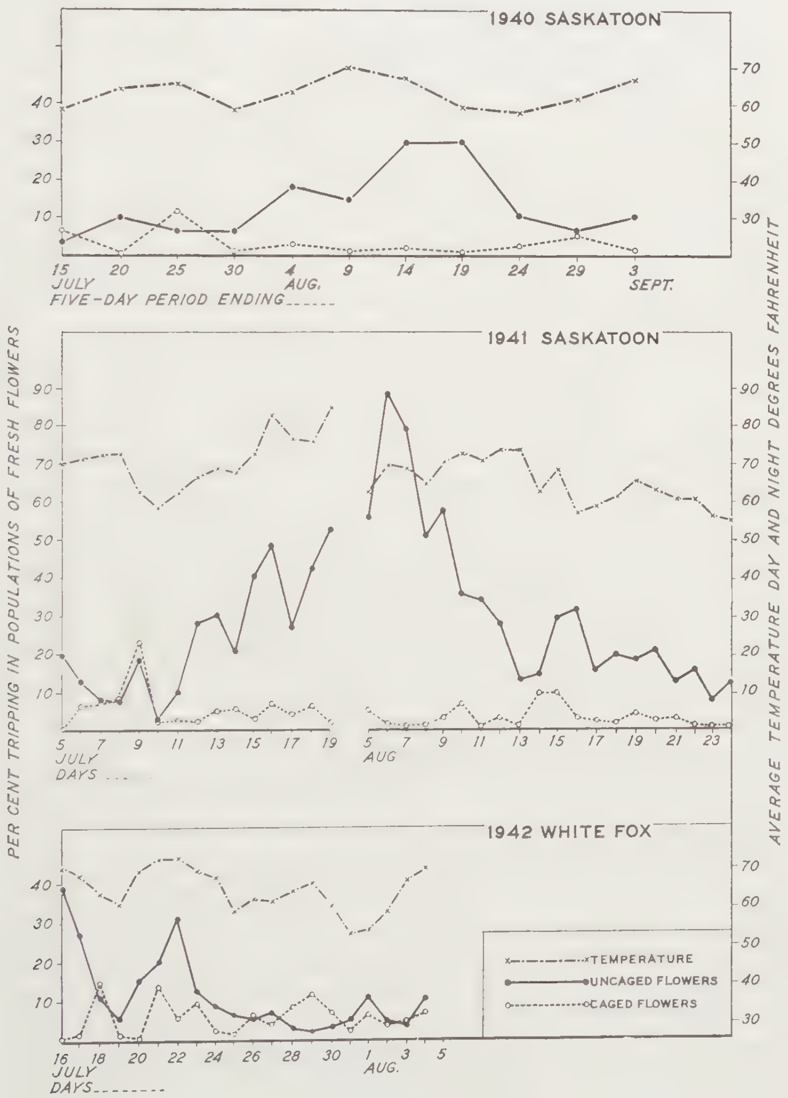


FIGURE 4. The tripping behaviours of caged and uncaged alfalfa flowers studied 1940 to 1942, and their relation to temperature conditions.

for the 3 years, 1940 to 1942. The percentages of tripping for caged and uncaged flowers are shown together with the average daily temperatures. The relation of tripping and seed setting under open-pollination to various weather factors is indicated in Table 7 by simple correlations.

Under cages the amount of tripping remained uniformly low, while outside cages the amount of tripping was higher and showed remarkable fluctuation. Only on July 9, 1941, was tripping noticed to any extent under cages. This was due to a shower of 0.11 inches which fell between the hours of 4 and 5 p.m. Spraying flowers artificially was also found to cause some tripping. Rain tripping, however, resulted in poor pod setting. Outside cages in 1940, very good tripping took place during the first 3 weeks of August. The weather for this period was hot, dry, and somewhat windy. In 1941 uncaged flowers showed very abundant tripping during late July and early August. Little precipitation was recorded during the entire 1941 period. In the 1942 studies at White Fox, tripping was fairly abundant in mid-July, but during late July and early August scarcely any tripping was found. July 19 and the days July 24 to August 2 were very unsuitable for tripping because the weather was cool and cloudy with frequent showers.

Table 7.—Correlations of tripping and pod setting with weather conditions for 24-hour periods, 1940-42—uncaged condition

Factors considered	Value of *r*		
	1940	1941	1942
% Tripping—Temperature day (8 a.m.—8 p.m.)	+ 0.29	+ 0.44	+ 0.46
% Tripping—Temperature night (8 p.m.—8 a.m.)	+ 0.34	+ 0.41	+ 0.64
% Tripping—Temperature day and night	+ 0.24	+ 0.54	+ 0.58
% Tripping—Temperature 2 p.m.	+ 0.29	+ 0.51	+ 0.44
% Tripping—Humidity day (8 a.m.—8 p.m.)	− 0.37	+ 0.03	+ 0.26
% Tripping—Humidity night (8 p.m.—8 a.m.)	− 0.65	+ 0.06	− 0.24
% Tripping—Humidity day and night	− 0.63	− 0.25	+ 0.24
% Tripping—Hours sunshine per day	− 0.54	+ 0.43	—
% Tripping—Wind velocity miles per day	+ 0.34	− 0.03	—
% Tripping—Per cent pod setting	+ 0.61	+ 0.55	+ 0.65
% Pod setting—No. of seeds per pod	—	+ 0.84	—
Value of *r* 5% point	0.60	0.35	0.46
Value of *r* 1 % point	0.73	0.45	0.58

From Table 7 it is apparent that temperature is a most important factor influencing tripping. In 1941 and 1942, correlations of the percentage daily tripping with temperatures for the day, for the night, for day and night, and at 2 p.m. showed significance in all but one case. This was in 1942 when only a positive relationship was found between the percentage tripping and temperature at 2 p.m. In 1940, significant correlations were found between relative humidity and the percentage tripping. A significant correlation was also found between the hours of sunshine and tripping in 1941. No significant correlation was found between wind velocities and tripping. The strong relationships shown between tripping and pod setting, and pod setting and the number of seeds per pod, indicate that the tripping trends shown in Figure 4 reflect actual trends in seed yields. This relationship of tripping to pod setting is to be expected in view of the dual rôle of wild bees as tripping and cross-pollinating agents.

Unfortunately, no satisfactory index of the abundance of wild bees was available for correlation purposes. In 1940, *Megachile* bees were observed tripping flowers but their full importance was not realized. Counts were not made in 1941, but from general observation at Saskatoon it can be stated that none was present before July 13 and few after September 1. In 1942, at White Fox, bee counts were made on 20 small areas each day at 10 a.m. at the site of flower observation. The correlation of tripping and bee counts, however, was not significant ($r = +0.39$). Had more extensive bee counts been made, and counts taken several times during the day, it is likely that a strong positive correlation would have been found.

The bearing of temperature on the amount of tripping is also shown from a study of tripping for various day periods. In the 1941 studies at Saskatoon, flowers were examined every 4 hours from 4 a.m. to 8 p.m. during the period July 5 to July 19. The following year at White Fox, this study was repeated from July 20 to July 26. At White Fox no observations were made at 4 a.m., nor were observations made of caged flowers. All the flowers were grouped according to the period in which they tripped, and amount of tripping and seed setting of each group determined. Table 8 gives a summary of the results of this study.

TABLE 8.—TRIPPING AND POD SETTING OF ALFALFA BY DAY PERIODS

Treatment—Day period	Flowers tripped	Tripped flowers as % of total tripped flowers	Percentage of tripped flowers later setting pods	Seeds formed	
				Per pod set	Per flower tripped
	no.	%	%		
1941—Saskatoon, 20 plants, July 5-19					
Caged 8 p.m.— 4 a.m.	15	9.2	46.7	2.0	0.93
4 a.m.— 8 a.m.	26	16.0	46.2	2.2	1.00
8 a.m.—12 noon	45	27.6	37.8	1.4	0.53
12 noon—4 p.m.	40	24.5	25.0	1.6	0.40
4 p.m.—8 p.m.	37	22.7	29.7	1.8	0.54
Total	163				
Uncaged 8 p.m.— 4 a.m.	15	4.6	53.3	2.9	1.53
4 a.m.— 8 a.m.	31	9.5	58.1	2.9	1.71
8 a.m.—12 noon	104	31.8	56.7	3.0	1.68
12 noon—4 p.m.	140	42.8	64.3	3.5	2.26
4 p.m.—8 p.m.	37	11.3	70.3	3.5	2.49
Total	327				
1942—White Fox, 40 plants, July 20-26					
Uncaged 8 p.m.— 8 a.m.	58	23.7	13.8	5.1	0.71
8 a.m.—12 noon	91	37.1	47.2	3.9	1.85
12 noon—4 p.m.	71	29.0	53.5	4.1	2.21
4 p.m.—8 p.m.	25	10.2	56.0	2.8	1.56
Total	245				

It may be seen from Table 8 that tripping under open-pollination generally occurs from 8 a.m. to 4 p.m. In 1942 there is an indication that considerable tripping occurs previous to 8 a.m. Under cages, tripping is more uniformly distributed but again occurs more commonly during the hotter periods of the day. An observation of the last column of the table indicates that tripping during the day for uncaged flowers results in better seed setting than tripping during the night. For caged flowers somewhat the reverse situation holds. Flowers tripping during the night form more seeds than flowers tripping during the day.

The Effect of Variations in Automatic Tripping, Self- and Cross-Fertility

In an earlier section of this paper the variation among alfalfa strains with respect to tripping and seed setting behaviour was noted. Of special interest was a group of high seed setting plants which set seed well under cages and in the open. In contrast to these selections, Grimm plants set but little seed when insects were excluded. A more detailed description of these two plant groups is given in Table 9 where the reactions of 3 selections and 16 Grimm plants are recorded. The selections are less outstanding than others since found but, none the less, their superior seed setting under caged conditions is quite evident.

Upon caging it is apparent from Table 9 that plants differed greatly in their ability to trip automatically. The selections as an average were considerably higher in percentage tripping than the random Grimm. There is also a marked difference between plants in their degree of fertility as shown by the percentage of tripped flowers which set pods and the number of seeds per pod set. Some plants tripped readily and were quite highly fertile (S-40-2), others tripped readily and were comparatively sterile (46-16), and still others were comparatively non-self tripping and sterile (46-14). There were various intergradations and combinations of these characters.

Under open pollination conditions there was still a marked difference between plants in extent of tripping although the difference was not as great as under cages. There was an indication of a relationship between the extent of tripping under the two sets of conditions, but several plants tripping favourably under open pollination tripped poorly when caged. With respect to fertility under open pollination a wide range was again observed, the percentage of tripped flowers forming pods varying between 14.3 and 84.6 and the number of seeds formed per pod varying between 0.5 and 4.5.

Comparing the selection with random Grimm it is seen that under caged conditions the selections on the average are more than twice as high in automatic tripping and in percentage of tripped flowers setting pods and are somewhat higher in number of seeds per pod set. The occasional random plant is as high or higher than the selections with respect to any one of these phenomena when considered singly but none of the random plants combine a high degree of self-tripping with high fertility as do the selections. The end result is that the selections set 0.6 seeds per flower observed and the random plants 0.1 seeds. Under uncaged conditions, the differences persist although to a less marked degree between the selections and random plants in respect to percentage tripping and percentage

TABLE 9.—VARIATION IN ALFALFA PLANTS WITH REGARD TO THE PERCENTAGES OF TRIPPING AND POD SETTING FOR CAGED AND UNCAGED CONDITIONS—SASKATOON, 1941

Plant designation	Caged conditions					Uncaged conditions				
	Flowers observed	Percentage tripping	Percentage tripped flowers forming pods	Seeds formed		Flowers observed	Percentage tripping	Percentage tripped flowers forming pods	Seeds formed	
				Per pod set	Per flower observed				Per pod set	Per flower observed
		%	%				%	%		
1941—High seed setting selections—Saskatoon										
S-32-12	103	34.0	57.1	2.0	0.4	99	64.6	76.6	3.0	1.5
S-40- 1	56	67.8	47.4	1.6	0.5	53	73.6	76.9	2.5	1.4
S-40- 2	85	81.2	55.1	1.8	0.8	81	80.2	72.3	3.6	2.1
[Average] (weighted)		58.1	53.5	1.8	0.6		72.1	75.0	3.0	1.6
1941—Random Grimm plants—Saskatoon										
7-17	47	38.3	00.0	—	0.0	47	68.1	21.9	2.0	0.3
9-11	40	67.5	25.9	0.3	0.0	36	80.6	44.8	0.5	0.2
9-27	71	18.3	38.5	1.8	0.1	73	46.6	44.1	2.3	0.5
9-28	91	42.8	15.4	1.0	0.1	90	38.9	14.3	0.8	0.0
10-16	52	13.5	28.6	0.5	0.0	46	43.5	70.0	3.3	1.0
10-21	74	12.2	22.2	1.0	0.0	76	38.2	79.3	2.0	0.6
12-14	41	2.4	0.0	—	0.0	45	55.6	60.0	3.7	1.2
12-22	51	9.8	0.0	—	0.0	52	80.8	45.2	3.6	1.3
12-19	47	29.8	7.1	1.0	0.0	48	58.2	25.0	0.7	0.1
23- 3	90	38.9	34.3	1.4	0.2	91	62.6	56.1	2.9	1.0
23- 7	92	19.6	44.4	1.9	0.2	88	63.6	73.2	3.5	1.6
27-14	45	4.4	50.0	3.0	0.1	46	63.0	55.2	2.4	0.8
46- 7	49	22.4	36.4	0.8	0.1	45	84.4	34.2	2.3	0.7
46-14	92	13.0	0.0	—	0.0	85	54.1	56.5	4.5	1.4
46-16	46	60.9	21.4	0.7	0.1	45	86.7	51.3	2.2	1.0
58- 8	79	15.2	25.0	2.5	0.1	83	62.6	84.6	4.0	2.1
[Average] (weighted)		24.9	23.1	1.3	0.1		59.3	52.4	3.0	0.9

of tripped flowers setting seeds. In regard to seeds formed per pod set the selections are no higher than the random Grimm but because of the higher tripping and pod formation the number of seeds per flower observed is 1.6 in the selection compared to 0.9 in the random material.

Although the selections because of higher tripping and fertility somewhat outyielded the random plants their value as breeding material may be debatable. These characteristics may result in a fairly high degree of selfing even under open pollination conditions, to the detriment of the forage and seed yield of the next generation (15).

A further study was made in 1942 of the differences between high seed setting selections and random Grimm. One-half of each of 10 plants of each group were caged for the entire flowering season. No detailed flower observations were made but the self- and cross-fertility was determined by selfing 20 flowers and crossing 20 flowers in each plant. Pollination treatments were replicated in selfing and crossing 10 flowers on each of 2 dates with a 2-week interval between dates. After harvesting the selfed and crossed racemes the balance of the caged and uncaged portions of the plants were harvested. Seed yields were determined and expressed as percentages of straw weights. The results of this study are presented in Table 10.

Table 10.—The relation of seed yields under caged and uncaged conditions to self- and cross-fertility—Saskatoon, 1942

Strain No.	Seed yields—Seed weight as percentage of straw weight		No. of seeds per 10 flowers	
	Caged	Uncaged	Self-pollinated	Cross-pollinated
High seed setting selections				
S–38– *10*	11.8	7.0	23.5	61.5
S–38– *31*	8.6	9.8	9.5	33.5
S–38– *33*–1	13.8	14.7	16.5	30.0
S–39– *49*	16.7	27.5	25.5	61.0
S–39– *54*	6.1	12.1	7.0	44.0
S–40– *47*	15.4	18.5	10.0	59.0
S–40– *85*	12.6	9.9	29.5	30.5
S–40– *88*	4.5	14.1	10.0	37.0
S–40–*104*	15.7	8.6	30.5	59.0
S–40–*182*	15.7	11.1	3.0	45.0
Average	12.1	13.3	16.5	46.0
Random Grimm plants				
1008–13– 8	0.0	1.5	1.0	53.5
1008–13– 9	7.3	11.1	2.5	33.0
1008–13–12	1.0	4.4	17.0	26.5
1008–13–13	1.7	3.6	17.5	46.0
1008–27– 6	0.5	0.6	4.5	39.0
1008–27– 7	1.2	1.7	7.5	31.0
1008–27–11	0.3	0.7	1.5	51.5
1008–27–12	0.0	0.4	3.5	23.0
1008–34– 5	0.5	0.4	0.0	29.0
1008–34– 6	2.8	3.8	1.0	38.0
Average	1.5	2.8	5.6	37.0

The selections set considerable seed under both caged and uncaged conditions. Caging thus had very little influence on seed yield of these plants. The random Grimm set very poorly under both sets of conditions, although on the average under open pollination the yield was about double that from under the cage. When selfed it is seen that the selections were much more self-fertile than the random plants. The selections in general were also more cross-fertile than the random plants. Between groups and also between plants in groups there is thus a wide range in automatic tripping, self-fertility and cross-fertility.

Comparing Tables 9 and 10 it is seen that in 1941 the random plants under open pollination compared more favourably with the selections than they did in 1942. This was due to the presence of a fair number of leaf-cutter bees in 1941 resulting in considerable tripping and cross-pollination. In 1942 no leaf-cutter bees were found working in alfalfa at Saskatoon and consequently it is likely that the seed setting which took place under open pollination was the result of automatic tripping accompanied by self-fertilization.

The Extent of Natural Crossing

The extent of cross-fertilization in alfalfa was determined by using selections breeding true for the recessive, white-flowered character. Open-pollinated seed was collected from white-flowered plants in 1941, and the progeny of 359 plants observed for flower colour in 1942. The amount of crossing varied from 91.0 to 100% with an average value of 94.2%. A population of 17 plants from caged seed from these plants showed 41.2% crossing. Some of the white-flowered plants used were somewhat more self-sterile than random Grimm plants and these showed complete cross-fertilization. Recently high seed setting white-flowered selections have been obtained and will be used in finding the degree of crossing of high seed setting selections under a variety of conditions.

DISCUSSION

The results of these investigations are in close agreement with those of Tysdal (14) in which it was found that alfalfa seed setting depends largely on the activity of tripping and cross-pollinating insects. It has been suggested that high yields in northern Saskatchewan are due to the podsolic soils of the area, or to higher humidities and more strongly fluctuating temperatures than found in prairie regions. From these studies it appears as if the suitability of the area for alfalfa seed production is due to its relatively high population of leaf-cutter bees.

Where large fields are concerned and high yields produced, it is difficult to comprehend sufficient bee activity to account for all the tripping required. It must be kept in mind, however, that because of their rapid rate of operation high concentrations of these bees are not necessary. Their activity is almost unknown to growers on account of their rapid elusive movements. Leaf-cutter bees are not invariably found in good seed setting fields as populations fluctuate widely throughout the flowering season. Whether these fluctuations in numbers are due to migrations to more attractive sources of flower, or to actual changes in the number of bees is not known.

It must be emphasized that factors other than the number of wild bees may influence seed setting. The exceptionally poor yields in the White Fox area in 1942 were largely due to a reduction and thinning of stands by winter killing, and damage to seed from early fall frosts. Poor seed setting in certain fields in 1941 was associated with high *Lygus* bug counts. Then again, young fields with thin stands tend to outyield old fields with thick stands. Cultural practices such as the spring burning of combine stubble, the use of fertilizers, spring cultivation, and rejuvenation of stands by ploughing are being carried out by farmers with the belief that seed setting is benefited. It seems unlikely that these practices can improve yields by inducing automatic tripping. Yields are improved, in all probability, by the production of more attractive flower in greater abundance, or by the provision for better pod and seed formation subsequent to pollination.

With tripping insects a major factor influencing seed yields, practical recommendations must take into consideration methods of increasing their numbers and their activity in alfalfa fields. Tysdal (14) considered it sound agronomic practice to encourage the presence of leaf-cutter bees in fields and to study means for their artificial production. Salt (12) recommended leaving strips throughout alfalfa fields to provide nesting places. Considering that the nests of *Megachile* bees were found in stumps and logs it seems likely that the destruction of such wood around alfalfa fields will reduce bee numbers. Competing flower, especially that of weeds, should be kept at a minimum so as to force tripping insects to forage on alfalfa. Small increases or reductions in the acreage of alfalfa in a district will probably alter the amount of seed produced but little. Increasing the acreage of alfalfa will disperse bee activity, whereas reducing the acreage will bring about a more complete tripping of available flower. Increasing yields by mechanical trippers does not appear practical since no provision is made for the cross-pollination of flowers.

Until the life habits of these bees are better known, more definite recommendation cannot be made. The possibility of artificially increasing the numbers of these bees is not hopeless. It is uncertain whether varieties can be produced which will set seed independent of wild bees or dependent on honey bees. It is urged that at the present time attempts to improve seed yields in Saskatchewan be concentrated on finding more precisely of what importance *Megachile* bees are in alfalfa seed setting and what measures may be taken to use them to full advantage.

Selections which set seed well in the absence of insects because of their high degree of automatic tripping and partial self-fertility, appear an interesting and promising source of material for breeding improvement. Following cross-pollination these selections usually set more seed than ordinary Grimm plants. It is expected that under ideal seed setting conditions a high degree of crossing will prevail on account of partial self-incompatibility. How much crossing will occur under poor seed setting conditions because of wind or of other insects is yet unknown, but the amount is not expected to be great. Studies not reported here indicate that inbreeding in some lines of this material caused no marked reductions in vigour. Reductions in seed yields were pronounced, especially on poor seed setting years. The development of new strains from these selections

by selfed line and strain building methods is now being attempted. A study comparing the value of self-fertile and self-sterile lines in F_1 hybrid seed production is also in progress.

With seed setting dependent on wild bees the breeding problem is complicated. A proper evaluation of inbred lines and improved strains with regard to seed yields can be made only under comparatively good seed setting conditions. The selections of strains under poor seed setting conditions alone, as is done at many Canadian stations, may lead to the development of self-fertile strains which show no superiority when grown commercially in seed production areas.

SUMMARY

1. Caging alfalfa with screen cages of various types at Saskatoon, Sask., and White Fox, Sask., resulted in severe reductions in the production of seed. These reductions were the result of decreased tripping, and inferior pod setting and pod filling.

2. Caging treatments were found to be detrimental to seed setting through the exclusion of tripping and cross-pollinating insects rather than through changes in temperatures, humidities and light intensities.

3. Significant correlations were found between the amounts of tripping, the amounts of seed setting, and the abundance of leaf-cutter or *Megachile* bees for a total of 116 alfalfa fields visited in the White Fox area in 1941 and 1942. Leaf-cutter bees were not as abundant as honey bees but were more abundant than bumble bees.

4. *Megachile* bees were found to visit alfalfa flowers at an average rate of 17.3 per minute, tripping nearly all flowers visited. Flowers which they tripped formed 2.55 seeds on the average. Flowers tripped by hand set 0.42 seeds on the average.

5. Nests of leaf-cutter bees were found in stumps and logs of the balsam poplar adjacent to alfalfa fields.

6. *Megachile (Delomegachile) vidua* Sm. was the leaf-cutter species most commonly collected in sweeps within alfalfa fields.

7. Temperature was found to be the most important of the weather factors influencing the tripping of alfalfa flowers.

8. Under open-pollination most of the tripping takes place between the hours of 8 a.m. and 4 p.m.

9. Occasional plants set seed well without insect visitation because of a high degree of automatic tripping and partial self-fertility. Marked variations were found among plants of Grimm alfalfa in tripping and pod setting behaviour.

10. The self-pollination of self-fertile selections and random Grimm material gave averages of 1.65 and 0.56 seeds per flower, respectively. Cross-pollination gave averages of 4.60 and 3.70 seeds per flower for the two respective groups.

11. An average of 94.2% crossing was found in alfalfa during 1941 at Saskatoon.

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BOOK REVIEWS

THE DIAGNOSIS OF MINERAL DEFICIENCIES IN PLANTS BY VISUAL SYMPTOMS. A colour atlas and guide. By T. Wallace. Published by His Majesty's Stationery Office, London. Price 10s.

This book has been written primarily for the use of technical officers and advisers in the British Isles concerned with problems of crop production. It has also been made readable for progressive farmers, vegetable growers, and fruit growers. It is not as elaborate a publication as *Hunger Signs in Crops* because it has been produced in Britain under wartime conditions. However, it contains 52 pages of text on essential points in the nutrition of plants, soils in relation to the supply of mineral nutrients, methods of determining mineral deficiencies in crops, and visual symptoms of deficiencies in crops, together with a chapter on the use of the visual method of diagnosis in the field. The remaining 60 pages of the book include 114 colour plates from colour photographs, running 2 plates to the page with descriptive titles.

The following number of plates appear for the various mineral deficiencies: phosphorus 13, calcium 4, magnesium 22, potassium 23, iron 7, manganese 17, boron 16, together with 6 plates of potatoes in sand culture showing deficiencies in nitrogen, phosphorus, calcium, magnesium and potassium; there are 5 plates showing foliage symptoms which may be confused with nutrient deficiencies including virus yellows in sugar beets, insect injury to cabbage and turnip, and chloride injury to red currant. The plates include mainly deficiency symptoms on potatoes, sugar beets, turnips, cauliflower, kale, tomatoes, beans, mangold, but include also several plates on gooseberries, black currants, raspberries, strawberries, and apples. The plates are not large, averaging about 3″ x 3″. Colour photographs are well taken and in many cases show field backgrounds.

An additional interesting feature of the book is a table of suitable indicator plants. For any one deficiency element a list of indicator plants is given, with the special symptoms which these plants show and references to the plate numbers where these symptoms are illustrated. There is also in tabular form a guide to common symptoms of mineral deficiencies of cereals, Brassica crops, beet crops, potatoes, beans and peas, clovers, carrots and parsnips, tomatoes and fruit crops.

This publication would appear to be a valuable addition to the literature on visual symptoms of mineral deficiencies, and should be very useful to the research workers in connection with the reading of current literature in British publications in which colour plates could not be provided with the individual papers. It will also be of interest to compare the plates in this publication with plates published on this continent.

H. L. T.

THE PRODUCTION OF SEED OF ROOT CROPS AND VEGETABLES. Imperial Agricultural Bureaux Joint Publication No. 5. Available from Imperial Agricultural Bureaux, Central Sales Branch, Agricultural Research Building, Penglais, Aberystwyth, Great Britain. Price 3s.

Among the numerous readjustments that have had to be made since 1939 in agricultural production in countries outside Europe, those concerned with the supply and distribution of seeds of agricultural and horticultural plants demand an important place. Isolation from the former seed producing countries of central Europe and the great risks affecting the transport of consignments of seed across the seas from one country to another have led to the attempt to achieve self-sufficiency in seed supplies in all countries where production is at all possible. This development is probably more marked with respect to seeds of root crops and vegetables than with any other seed. New areas have had to be located which are best suited to this type of production, new techniques have had to be studied and passed on to the cultivators, and attention has had to be given to the choice of adapted varieties and to the distribution and marketing of the final product.

This publication describes these new developments in as many countries as have been accessible under present abnormal conditions. The various articles describe the extension of the production of seed away from the areas where conditions especially favoured this industry to countries less suited in many cases, and in some cases, for example, Scotland, Sweden and Canada, to countries actually on the fringe of the possible seed producing latitudes.

The Canadian contributions to this publication include an article on root crop seed production by T. M. Stevenson and R. M. MacVicar, and vegetable seed production by T. F. Ritchie, of the Central Experimental Farm, Dominion Department of Agriculture, Ottawa. Articles are included from England, Scotland, Netherlands, Sweden, United States of America, Canada, Australia, New Zealand, South Africa, and the Colonial Empire.